

**EVALUATION OF NUTRITIONAL, CHEMOTHERAPEUTIC AND EDUCATIONAL
APPROACHES TO MANAGE GASTROINTESTINAL NEMATODES AND IMPROVE
SMALL-SCALE GOAT FARMING**

by

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ABSTRACT

Small-scale goat farmers from south-western KwaZulu-Natal Province, South Africa, identified gastrointestinal helminths, dry-season feed scarcity and poor reproductive performance as major production constraints and highlighted the paucity of information on goat health and management. The research and extension processes adopted to address these problems comprised on-station experimentation, followed by on-farm validation combined with the participatory dissemination of both study findings and relevant information on goat health care. The approach included the use of the FAMACHA[®] system to assess anaemia, a characteristic symptom of infection with the gastrointestinal nematode, *Haemonchus contortus* (Rudolphi, 1803). On-station experimentation indicated that urea-molasses block supplementation during the dry, winter season was a cost-effective option. Unfortunately, when tested on-farm, the value of such supplementation proved inconclusive, possibly due to low block consumption and further research into alternative and palatable protein supplements for goats is suggested. However, tactical anthelmintic treatment with ivermectin effectively reduced faecal egg counts and is recommended, as is concurrent symptomatic anthelmintic treatment, as determined by the FAMACHA[®] system, since this practice appeared to improve reproductive capacity. Investigations to better adapt the FAMACHA[®] system to goats is, however, recommended. A flexible training framework was developed with the collaboration of the farmers, providing them with advice on goat health and management. This ‘hands-on’ approach encompassed regular meetings geared to the farmers’ current expertise and exploited the on-farm experimentation as a training vehicle. The process nurtured local farmer ‘champions’, strengthened the extension skills of researchers and technicians and incorporated the development of a *Goatkeepers’ animal health care manual*. Indications are that the use of such an approach has considerable potential for the development of goat farming. Moreover this process, which is relatively novel for South Africa, is equally applicable to other similar agro-ecological zones. Access to veterinary and agricultural inputs in areas where communal grazing is practised could be vastly improved and a case is made for universities, researchers, extensionists and farmers to collaborate to encourage the long-term sustainable development of these communities.

PREFACE

The experimental work described in this thesis was carried out from April 2002 to December 2005 at Onderstepoort Veterinary Institute, Pretoria, South Africa and in Bulwer, KwaZulu-Natal Province, South Africa with the co-operation of local farmers and in association with the Farming Systems Research Section, KwaZulu-Natal Department of Agriculture and Environmental Affairs, Pietermaritzburg, South Africa. The thesis itself was compiled under the supervision of Professor Frits H J Rijkenberg and Mr Steven H Worth of the Centre for Environment, Agriculture and Development, Faculty of Science and Agriculture, University of KwaZulu-Natal, Pietermaritzburg and Dr Leslie J S Harrison of the University of Edinburgh, Midlothian, Scotland.

Except where due acknowledgement has been made, these studies represent original work by the author and have not otherwise been submitted in any form for any degree or diploma to any university.

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ABBREVIATIONS

ARC	Agricultural Research Council of South Africa
BLOCK goats	goats supplemented with urea-molasses blocks (see Chapter 2)
<i>ca.</i>	<i>circa</i>
epg	eggs per gram of faeces
FAMACHA [®]	FAffa MAlan CHArt, a colour-coded card that is used to classify a sheep or goat as anaemic or not based on the colour of the conjunctival mucous membrane
FSR	Farming Systems Research
F [®] /TACT goats	goats scored as anaemic on 3 January 2005 and tactically treated with ivermectin (see Chapter 2)
L ₃	infective third-stage nematode larvae
n.d.	no date
NO-BLOCK goats	goats not supplemented with urea-molasses blocks (see Chapter 2)
NON-F [®] /TACT goats	goats not scored as anaemic on 3 January 2005 but tactically treated with ivermectin (see Chapter 2)
NON-F [®] /NON-TACT goats	goats not scored as anaemic on 3 January 2005 and not tactically treated with ivermectin (see Chapter 2)
OVI	Onderstepoort Veterinary Institute
RSA	Republic of South Africa

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Any findings, conclusions, opinions or recommendations expressed in this thesis and in the published articles are those of the authors and not necessarily of the organizations concerned, which do not accept any liability in regard thereto.

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Chapter 1

GENERAL INTRODUCTION

AIMS AND OBJECTIVES

This thesis examines various ways in which to optimize goat production in the small-scale farming sector. The ultimate objective of this work is to improve the livelihoods of goat farmers by helping them to make the best use of the resources available to them. The objective of the present study was to investigate the interaction between goat productivity, helminthosis and nutritional and chemotherapeutic interventions under the small-scale farming conditions of south-western KwaZulu-Natal Province. The immediate aims were to develop cost-effective and sustainable strategies to control gastrointestinal nematode infections in goats and to improve feed utilization. A further important aim was to provide the farmers with general advice on goat management.

As will be seen from the compilation and discussion of this thesis, the chapters differ in type and focus, from experimental, station-based, research to on-farm experimentation and extension. This is because there was a need to ensure rigour in the investigation of the scientific aspects of the nutritional and chemotherapeutic intervention strategies before testing them on-farm or before suggesting their use in the wider community. Furthermore, there was a need to convey the scientific facts as clearly and thoroughly as possible for the science to be shown to be relevant and potentially beneficial for the farmers.

IMPORTANCE OF THE SMALL-SCALE FARMING SECTOR IN THE REPUBLIC OF SOUTH AFRICA

There is a rural population of *ca.* 17.5 million people living below the rural poverty threshold in the Republic of South Africa (RSA) (Thornton *et al.*, 2002). A proportion of these people are farmers and Thornton *et al.* (2002) estimated that 10.6 million were livestock keepers. Of these, 3.50 million were in mixed-farming, rainfed, temperate production systems or tropical highlands; 3.12 million were in mixed-farming, rainfed, arid or semi-arid systems; 1.75 million were in rangeland-based, arid or semi-arid systems and were farming with livestock only; and a

further 1.15 million were to be found in mixed-farming, rainfed, humid or subhumid systems. The remaining 1.12 million were found in other types of production systems.

An official survey of large- and small-scale agriculture indicated that there were 614 000 farming operations in the previously designated 'homeland' areas and 84 000 in South Africa excluding the former 'homelands' (Shabalala and Mosima, 2002). Farming operations in the 'homelands' were characterized by small-scale and subsistence farming while those of the rest of South Africa were mostly large-scale commercial operations.

CHALLENGES FACED BY THE SMALL-SCALE FARMING SECTOR

Typically and as a result of several contributing factors, livestock production and reproduction in the South African small-scale farming sector is low. These rural communities are characterized by skewed demographics with high proportions of women, the aged and children. This is a legacy of the migrant labour systems in the RSA (Krecek *et al.*, 1999; Ntsime *et al.*, 2003; De Villiers, 2006). The people have poor access to facilities, infrastructure and finance while farmers have no security of land tenure. Their animals are grazed communally and they have little access to agricultural information and support services (Ngomane *et al.*, 2002). The result is that farmers are generally unaware of the latest available research results, technologies and approaches and are also lacking in self-confidence and self-worth (pers. obs., 2004).

As a result of all these challenges, this small-scale sector has been described as 'resource-poor'. The World Commission on Environment and Development (1987) stated that ' "resource-poor agriculture" relies on uncertain rain rather than irrigation and is usually found in developing regions difficult to farm - drylands, highlands, and forests - with fragile soils.' However, if this thesis is to serve to highlight the potential for improvement and development in this sector, it would seem inappropriate to focus on the deficiencies which the term 'resource-poor' implies. As such, the more neutral term 'small-scale' has been used in the introductory and concluding chapters of this thesis. The term 'resource-poor' has been used in the main body of the thesis (Chapters 2-5) as this was the designation employed when the papers were originally submitted for publication.

IMPORTANCE OF LIVESTOCK IN SMALL-SCALE FARMING COMMUNITIES

Small-scale farmers often rely on a variety of sources of income, food and support as this spreads the risk in the case of a particular income-generating activity failing (Chambers, 1997; Stroud and Kirkby, 2000). Of these various activities, animal production may be one of the most critical, especially where land for crop or vegetable production is marginal (Peacock *et al.*, 2005). Usually more than one species of livestock is kept and each species fulfills multiple roles for the household (Perry *et al.*, 2002). In mixed crop-livestock systems of eastern, central and southern Africa, cattle are the priority species, followed by goats and sheep, and then poultry (Perry *et al.*, 2002). Overall, though, goats are considered one of the most important farm animals because they provide their owners with products such as meat, milk, skins, hair and manure, are easily sold to provide a cash income, and because they are also very valuable for cultural and sociological reasons (Masika and Mafu, 2004; Peacock *et al.*, 2005).

Goats are valuable as they are relatively cheap and are often the first livestock asset acquired. They are able to adapt to widely different climatic conditions and are able to convert plant material that cannot be digested by humans into edible animal protein. Goats reproduce relatively quickly and may be exchanged or bartered for cattle which are more valuable and 'higher up' on the, so-called, 'livestock ladder' (Peacock *et al.*, 2005; Perry *et al.*, 2002).

CHALLENGES TO GOAT FARMING IN THE SMALL-SCALE FARMING SECTOR

There are many challenges in the small-scale farming sector that must be overcome if development is to take place (De Villiers, 2006). Poor or restricted access to relevant support services, new technologies, information and credit all have a detrimental effect on goat farming. Small-scale farmers also need access to basic information on animal diseases and their management (Masika *et al.*, 1997a,b; Letsoalo *et al.*, 2000; Wells and Krecek, 2001; Getchell *et al.*, 2002). In terms of physical challenges, one of the most important constraints is the availability of good quality feed (Peacock *et al.*, 2005). In the summer rainfall area of the RSA where veld (natural grazing) is utilized, the dry (winter) season is a critical period, characterized by a shortfall of palatable dry matter and nutrients (De Villiers, 2006). The shortage of nutritious feed on pasture

may be further exacerbated by the lack of land tenure. Farmers must graze their animals communally and there is consequently little incentive for individual farmers to invest in improving the grazing. Indiscriminate burning of the veld is considered to cause further deterioration of conditions (De Villiers, 2006). Stock theft and losses due to dogs or jackals are also frequently cited as problems (Ntsime *et al.*, 2003; Morin, 2004; Masika and Mafu, 2004; Peacock *et al.*, 2005; De Villiers, 2006).

Goats are particularly susceptible to a range of diseases, notably gastrointestinal parasitism (caused, *sensu lato*, by infection of the abomasum and small and large intestines with the trichostrongylid nematodes and nematodes belonging to other genera such as *Strongyloides*, *Bunostomum*, *Oesophagostomum* and *Trichuris*), fasciolosis (caused by infection with liver flukes, *Fasciola* spp.), broncho-pneumonia (caused by *Pasteurella multocida* and *Mannheimia haemolytica*) and tick-borne diseases such as heartwater (caused by *Ehrlichia ruminantium*) (Perry *et al.*, 2002). Ectoparasites such as ticks and lice may also be very important because they cause anaemia in young stock (Smith and Sherman, 1994; Bath and De Wet, 2000). In endemic areas, anthrax, peste des petits ruminants and goat pox assume greater importance, although the latter two diseases do not occur in the RSA. A very important production loss in goats results from neonatal mortality which can be caused by a number of factors including poor management, inadequate nutrition and disease.

Gastrointestinal parasitism in small ruminants is a disease caused by infection with a number of nematodes parasitizing the abomasum and small intestine and, *sensu lato*, also the large intestine. In a recent study, it was given the highest global index as an animal health constraint impacting on the poor (Perry *et al.*, 2002). This reflected the wide geographical distribution of gastrointestinal parasitism in all production systems, the wide host species range, and its importance at the poor farmer level. It is indisputably a cause of serious production losses to small ruminants in sub-Saharan Africa (Connor *et al.*, 1990; Over *et al.*, 1992), and indeed the world over (Fabiyyi, 1987). The most important gastrointestinal nematode by far affecting sheep and goats is *Haemonchus contortus* (Rudolphi, 1803), both in the commercial and small-scale farming sectors (Boomker *et al.*, 1994; Vatta *et al.*, 2001, 2002a; Tsotetsi and Mbatia, 2003; Peacock *et al.*, 2005).

Haemonchosis was ranked amongst the top ten diseases affecting the animals of poor livestock farmers in eastern, central and southern Africa (Perry *et al.*, 2002).

H. contortus is a blood-sucking nematode found in the abomasum of small ruminants, posing a threat in the summer rainfall area of the RSA from about November to April when ambient temperature and rainfall are suitable for it to complete its life cycle on pasture (Horak and Louw, 1977; Horak, 1978; Boomker *et al.*, 1994). However, *H. contortus* may also be a threat in the cooler months of the year and periodically causes problems in the semi-arid regions of the country (Viljoen, 1964; Carmichael, 1972; Biggs and Anthonissen, 1982), as well as in the winter (Van Wyk *et al.*, 1989) and non-seasonal rainfall areas (Rossiter, 1964). Production losses due to haemonchosis are incurred through a combination of factors, including death of stock, reductions in growth rates, impaired reproductive capacity and poor carcass quality. In chronic infections, the disease is exacerbated when pasture is of poor quality (Allonby and Urquhart, 1975).

MANAGEMENT OF GASTROINTESTINAL NEMATODE INFECTIONS

In a brief history of the use of chemotherapy in the control of helminths (*i.e.* the use of anthelmintics), Reinecke (1983) lists the use, from around the turn of the 19th century, of various relatively toxic compounds such as arsenious acid, tartar emetic and oil of turpentine. Substances such as copper sulphate, carbon tetrachloride and tetrachloroethylene came into more popular use during the first few decades of the 20th century. Between the 1940s and 1960s, phenothiazine was regarded as the best anthelmintic for the control of sheep nematodes, but staining of the wool in sheep and side-effects in certain cattle breeds were problematic. By the late 1950s, the organophosphate compounds were being used as anthelmintics. The early 1960s saw the release of the benzimidazoles on the market (Gordon, 1961; Hebden, 1961) and this heralded the era of the relatively safe, broad-spectrum, highly effective and relatively cheap anthelmintics. The release of the benzimidazoles was, in turn, followed by the release of the broad-spectrum imidazothiazoles and later by the avermectins (Waller, 2006). Since the emergence of these broad-spectrum products, control of gastrointestinal parasitism has relied heavily, if not exclusively, on chemotherapy. The mid-spectrum organophosphates, the narrow-spectrum halogenated

salicylanilides and the broad-spectrum benzimidazoles, imidazothiazoles and avermectins represent the five classes of nematocidal anthelmintics currently available for use in sheep and goats (Sutherland, 2007). Unfortunately, the period from the 1960s to the present day has seen the development of nematode resistance to all these five classes of anthelmintics. This has been caused at least in part as a result of overuse, misuse or incorrect application of the anthelmintics (Waller, 2006). The occurrence of anthelmintic resistance is of particular concern where a nematode isolate is resistant to drugs in more than one or all the marketed anthelmintic groups, which is unfortunately common (Van Wyk *et al.*, 1997). No classes of anthelmintic with novel mechanisms of action have been released on the market anywhere in the world during the past 25 years. Even if anthelmintics with novel methods of action were released in the future (Kaminsky, 2007), the development of anthelmintic resistance to these new compounds will probably be inevitable. All previous evidence indicates that resistance has developed in all target organisms to the broad-spectrum antimicrobials, insecticides, fungicides and anthelmintics in chronological order following their release (Waller, 2006).

Anthelmintic resistance has been reported in sheep and/or goats from at least 14 African countries (see Fig. 1, Chapter 2). Most published African reports are from Kenya and South Africa. The majority of these concern *Haemonchus* spp. and are from large-scale commercial or institutional farms, but there are some from small-scale farming systems. In such systems in South Africa, resistance has been reported in sheep in one study (Van Wyk *et al.*, 1999) and in goats in another two studies (Vatta *et al.*, 2001; Bakunzi, 2003).

Where resistance is present, the management of helminths by chemotherapeutic means obviously becomes complicated. However, chemotherapy will remain an important component of helminth control until other practical methods of parasite control become readily available. Moreover, if the productivity of small ruminants is to be improved in line with the global visions of internationally funded research bodies (Perry *et al.*, 2002), this will call for an increased use of anthelmintics. Increased anthelmintic use is unfortunately the driving force for the development of anthelmintic resistance. There is therefore a great need for research into the appropriate and

sustainable use of anthelmintics in all farming systems as well as into relevant and cost-effective alternatives to their use.

Alternatives to the sole reliance on anthelmintics for parasite control include combining the use of drugs with grazing strategies, the use of vaccines, the administration of copper oxide wire particles, biological control (*e.g.* nematophagous fungi), nutrient supplementation (Waller, 1999), breeding of host animals for worm resistance (Gray, 1997), ethnoveterinary medicine (Githiori *et al.*, 2002) and the use of tanniferous plants and extracts (Paolini *et al.*, 2003).

Helminth vaccines and the use of nematophagous fungi are still being actively researched and evaluated and are not yet ready for field application, certainly not under the small-scale farming conditions of the RSA. Copper-containing compounds such as copper sulphate have long been known to have anthelmintic properties, but toxicity is a problem. More recently, copper oxide wire particles have been developed as a safer form for administration to ruminants grazing copper-deficient pastures (Dewey, 1977), and the administration of these particles has been shown to have anthelmintic effects. However, further evaluation for efficacy and safety in indigenous goats and as part of helminth control programmes is required. Likewise the use of ethnoveterinary medicine and of tanniferous plants and extracts require proper and thorough testing for efficacy and safety before their use can be recommended (Githiori *et al.*, 2002). The adoption of grazing strategies within a communal grazing system would require a considerable community effort which would currently be difficult to achieve. The exploitation of host resistance against parasites through selective breeding is perhaps one of the most sustainable practices, but the process is slow and must be a longer term rather than a shorter term strategy. Nutrient, specifically protein, supplementation on the other hand is an option which is ready for testing in the field (see pages 11-13 for further details). As stated above, field research is also needed into the more judicious use of anthelmintics than that currently practised, so that the development of resistance is slowed down for as long as possible.

INVOLVEMENT OF SMALL-SCALE FARMERS IN RESEARCH AND EXTENSION

It is important to involve farmers in the research process, in order to help ensure that the research gives rise to relevant recommendations that can be applied in a sustainable manner. The farmers' input is required from problem identification to the formulation of potential solutions, to the testing of such solutions and finally to the development of recommendations deriving from such research. In the process of identifying solutions, research stations came to play an important role in examining ways in which yields (*e.g.* from a particular crop or from a livestock product) could be optimized (Stroud and Kirkby, 2000). The results of such research were suited to large-scale commercial operations which were able to access the resources (*e.g.* fertilizers and equipment) necessary to mimic on-farm the controlled conditions of the station. Typically, therefore, technology development occurred on-station and the solutions and technologies were delivered to farmers by extension personnel in a process referred to as 'transfer of technology' (Conroy, 2005; Worth, 2006). However, this conventional station-based agricultural research approach failed to achieve the expected results in the small-scale farming sector of the developing world (Stroud and Kirkby, 2000). Small-scale farmers' circumstances were and still are different from those of large-scale farmers. The small-scale farmers are more vulnerable to failure than the large-scale farmers, *e.g.* the death of one animal to a farmer that only owns three goats, would be a much greater loss at the household level than the same loss for a large-scale farmer that owns 300 goats. In addition, while possessing fewer livestock assets, these may be more susceptible to disease as a result of an inherent poorer level of nutrition and the lack of disease prophylaxis. Small-scale farmers therefore employ specific farming practices and a greater diversity of those to manage these risks and uncertainties. In allocating scarce resources, the stability of the enterprise and its survival in the shorter term are more important than optimizing the yield of a particular commodity. Technological solutions developed on-station in the past were therefore often inappropriate for the small-scale farmers.

This recognised deficit led to the development of participatory processes, including participatory situational analysis and participatory technology development (Conroy, 2005). The farmers' own management type and priorities received greater recognition and researchers assumed

a more supportive role. Extension came to be seen as an integral part of a human development programme (Worth, 2006). On-farm research has an exploitable advantage over on-station experimentation as it allows greater involvement and hence feedback from the farmer (Collinson, 1987; Norman *et al.*, 1994; Schiere *et al.*, 2000; Snapp *et al.*, 2002; Pound, 2007).

SELECTION OF TARGET COMMUNITIES

In April 2000, extension staff of the KwaZulu-Natal Department of Agriculture and Environmental Affairs identified the neighbouring farming communities of Nkwezela, Hlafuna and Njobokazi as an area that would benefit from on-farm client-orientated research (De Villiers and Letty, 2001). The communities are located near the town of Bulwer (Fig. 1), south-western KwaZulu-Natal Province, South Africa, and are situated in the Ingwe Local Municipality, which lies within Sisonke District Municipality.

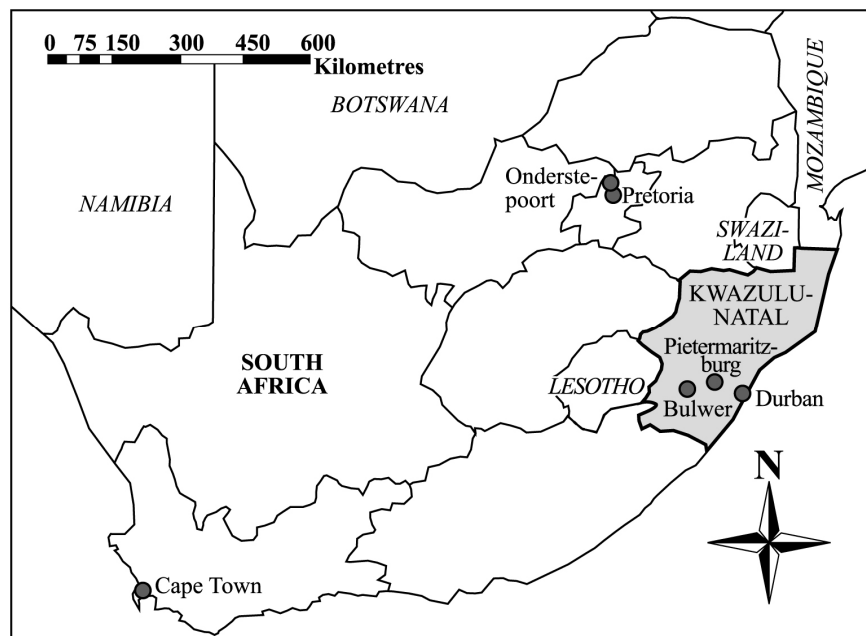


Fig. 1: Map of South Africa indicating the location of KwaZulu-Natal Province, certain major cities, Onderstepoort, site of the on-station work, and Bulwer, site of the on-farm work

The topography of the study area generally comprises rolling hills to mountainous areas, with moderate slopes and arable lands (Camp, 1997). The altitude range is 1 400-1 800 metres above sea-level. ‘Summer’ is from December to February and ‘winter’ from June to August. The

mean annual rainfall is 1 225 mm with the highest rainfall in January (*ca.* 201 mm) and the lowest in July (*ca.* 16 mm). The natural vegetation of the area is fire-maintained grassland and communal grazing of cattle, goats, sheep and horses is practised. The area has moderate to high agricultural potential, but soils are impoverished and require expensive inputs of lime and fertilizers (Camp, 1997; De Villiers and Letty, 2001).

Essentially all of Zulu origin, the population of Nkwezela, Hlafuna and Njobokazi, grew from 3 447 to 3 788 individuals between 1996 and 2001. Unemployment rose from 26 % to 39 % over the same period (Ntsime *et al.*, 2003; Jennings, 2004). In 2001, the demographics of the villages were skewed with greater proportions of women (56 %) than men (44 %) and a large proportion (58 %) of the population under the age of 20. The proportions of households headed by, women, children and the elderly, traditionally vulnerable groups, were 68 %, 3 % and 32 %, respectively. This situation was reflective of migration of the employable persons, especially the men, to work in the cities. Over 90 % of individuals had at least very basic education. There was poor access to electricity, clean potable water, adequate sanitation and refuse removal.

During initial ‘diagnostic’ meetings and survey work carried out by the Farming Systems Research (FSR) Staff of the KwaZulu-Natal Department of Agriculture and Environmental Affairs in Nkwezela, chickens, goats and cattle were identified as being the most frequently kept livestock (De Villiers and Letty, 2001). General livestock-related problems mentioned were theft, poor livestock production, animals in poor condition and insufficient grazing for livestock, mainly as a result of burning of the natural pasture. A need for information on livestock diseases, the potential causes of livestock deaths and the proper use of medication was expressed. The FSR Staff made a decision to examine goat production in the area in more detail as the important developmental potential of these small ruminants was recognized (Peacock *et al.*, 2005). Problems mentioned by farmers during the ‘diagnostic’ phase specifically affecting goats were diarrhoea, gastrointestinal helminths and poor reproduction. During follow-up survey work, diarrhoea, deaths due to unknown causes, coughing and theft were identified as being the major problems affecting this species (Mapeyi *et al.*, 2006). Research work in the nearby community of Impendle during 1998-2000

provided further evidence that helminths (specifically nematodes) and dry-season feed shortages were a problem in the region (Vatta *et al.*, 2002a,b).

IDENTIFICATION OF APPROPRIATE SOLUTIONS

Since few options had been tested to control helminths, to overcome dry-season, winter feed shortages and to improve the reproductive capacity of goats in the small-scale systems of south-western KwaZulu-Natal, a clear area for research presented itself. Of those options available for testing, nutrient supplementation appeared to be one of the most promising, given the potential dual benefits on improving the nutritional status of the animals and on mitigating the effects of nematode parasitism. In the absence of proven strategies that do not use anthelmintics to manage internal parasites, the use of chemotherapy was unavoidable. However, there was much scope for investigating the sustainability of methods of anthelmintic use, including tactical and symptomatic anthelmintic treatments, which are discussed in more detail below.

Nutritional supplementation

Considerably more work has been carried out to examine the interaction of nutritional supplementation with gastrointestinal nematode parasitism and productivity in sheep than in goats (Hoste *et al.*, 2005), and hence the following discussion focuses on the former species. The sheep is, fortunately, a physiologically close model for the goat. Gastrointestinal parasites exert their effect on host nutrition in a number of ways. While parasites are known to cause anorexia (a reduction in voluntary feed intake), the exact causative mechanisms are not yet known. Parasites cause endogenous protein, including whole blood, plasma, sloughed endothelial cells and mucus, to be lost (Knox and Wan Zahari, 1998). Depending on where in the intestine the endogenous protein losses occur, the protein will either be reabsorbed distal to the site of infection, further digested in the large intestine, absorbed as ammonia and excreted as urea in the urine, or excreted in the faeces. There appears to be little effect on the actual digestion and absorption of protein (Poppi *et al.*, 1986; Bown *et al.*, 1991). Rather it seems that there is poor protein deposition after absorption in parasitized ruminants (Coop and Sykes, 2002). Protein is repartitioned away from muscle, skeletal

and bone growth to the processes of blood and plasma protein synthesis, to the repair of the damaged alimentary tract lining and to the mounting of host immune responses. Overall this leads to the poor growth seen in parasitized ruminants (Knox and Wan Zahari, 1998; Coop and Kyriazakis, 1999) as the parasites both reduce the supply of protein to the host's tissues and increase the demand for it, inducing a protein deficiency (Coop and Sykes, 2002). Ways of providing additional protein to counteract this protein deficiency are therefore required. This is of particular concern in young animals where poor nutritional status caused by seasonal influences on pasture growth or by the negative effects of gastrointestinal parasitism may have significant effects on growth, resistance to nematode parasites and later reproductive performance (Knox *et al.*, 2003).

Studies have shown protein, as opposed to carbohydrates, to be effective in reducing the adverse effects of parasites (Coop and Kyriazakis, 1999). When ruminants are fed a diet which contains high concentrations of nitrogen, surplus levels of ammonia are generated (Min and Hart, 2003). This is absorbed from the rumen and ultimately excreted in the urine. If protein degradation in the rumen can be reduced, the protein can pass through to the small intestine for digestion and absorption. This is called bypass protein (Chesworth, 1992) and it is found, for example, in the by-products of vegetable oil extraction, *i.e.* oil cake meals. It is particularly effective in the protein supplementation of parasitized ruminants (Coop and Kyriazakis, 1999).

In lambs infected with *H. contortus*, dietary protein supplementation has been shown to improve the development of host resistance (immunity to infection) and resilience (defined as the ability of an infected animal to maintain production at a level equal to that of an uninfected control) in animals on a diet with a higher protein level relative to those on a poorer protein diet (Steel, 2003). This applies to breeds that are susceptible to haemonchosis, while protein supplementation in resistant breeds appears to be unnecessary. The beneficial effects of short-term protein supplementation may be exploited in young animals and these effects may persist for at least 16 months (Datta *et al.*, 1999). However, this persistent effect may only be evident where the basal nutritional status of the supplemented animals is below that required for maintenance and slow growth, and where the animals have not yet achieved 40 % of their expected mature live weight when the period of nutritional deprivation occurs (Knox *et al.*, 2003).

In lambs infected with *Trichostrongylus colubriformis*, a response to protein supplementation is seen when the host's protein intake is close to the requirements for maintenance or low growth rates (Steel, 2003). Increasing the level of bypass protein leads to a reduction in faecal egg count and the expulsion of adult worms, although the supplementation does not affect the initial establishment of the infection with this species. The effects of improved protein nutrition on host resistance may only become apparent after the infection has been present for 10 weeks (Kahn *et al.*, 2000).

A limited number of studies in goats appear to confirm the results for sheep (Hoste *et al.*, 2005). However, supplementary feeding in goats seems to give rise to greater improvements in resilience than in resistance. Hoste *et al.* (2005) attributed this to the poorer ability of goats to develop immunity to gastrointestinal nematodes than sheep.

Supplementation of ruminants with protein tends to be expensive and this has stimulated researchers to look for locally available sources of protein as dry-season supplements, including leguminous browse species and their pods (Aganga and Wani, 1998; Sikosana *et al.*, 2004). In the target area for the present study, leguminous browse species were not readily available and were thus not suitable as an alternative nutritional supplement.

Another cheap source of nitrogen is that derived from non-protein nitrogen compounds such as urea. This is sold in liquid form for mixing with poor quality roughages or formulated into blocks or granules. Supplementation with non-protein nitrogen sources such as urea increases microbial digestion of ruminal cellulose which leads to increased amounts of microbial protein post-rationally and stimulates feed intake (Knox and Wan Zahari, 1998). Supplementation of sheep with urea or urea-molasses has been shown to improve appetite, weight gain and body condition score and mitigates the effects of endoparasites (Anindo *et al.*, 1998; Stear *et al.*, 2000). The effects of supplementation with urea-molasses on gastrointestinal parasitism and productivity had not been examined in indigenous goats in South Africa. Such investigations were therefore indicated.

Strategic, tactical and symptomatic anthelmintic treatments

Although supplementary feeding may assist in improving the development of resistance and resilience, even resistant individuals could potentially be killed through the intake of high numbers of larvae, owing to intrinsic damage to the tissues of the animals at contact sites. Similarly, resilient animals may be overwhelmed through the uncontrolled and excessive accumulation of larvae on pasture. As such, appropriate anthelmintic treatments would still be required.

Strategic drenching is the anthelmintic treatment of animals at specific times, based on the seasonal prevalence of the worms, or on management considerations such as breeding, lambing, tail docking or weaning (Van Schalkwyk *et al.*, 1995). Tactical drenching, on the other hand, is the treatment of animals when a large number of worms are anticipated such as after good rains at a time when temperature and pasture conditions are ideal for the free-living stages. Salvage or symptomatic treatment is defined here as the treatment of an animal showing clinical signs of worm infection and estimated to be in danger of dying if not treated.

Horak *et al.* (1976) recommended drenching at the end of November or early December (strategic), during February (tactical), during May (strategic) and, if necessary, further tactical drenching from December to April for the commercial farming systems in the summer-rainfall areas of South Africa. Strategic treatment of sheep, when the number of worms *in refugio*, is low has been shown to promote the selection of resistant nematodes (Van Wyk, 2001). It appears that neither tactical nor strategic treatments are given in the small-scale farming situation in the RSA. However, some farmers give salvage treatments when worm problems occur. Given that *Haemonchus* egg counts peak in about February, a tactical treatment in January would appear to be appropriate. Importantly the treatment would also be given at a time which should not promote the rapid development of anthelmintic resistance since there should be adequate numbers of susceptible infective larvae on pasture to dilute any larvae derived from eggs laid by resistant worms remaining in the goats after treatment (Van Wyk, 2001).

The FAMACHA® system

Named for its originator, the FAffa Malan CHArt system, or FAMACHA® system, is a method that assists in directing or ‘targeting’ anthelmintic treatment at those *Haemonchus*-infected individuals that truly require it and potentially helps to conserve the efficacy of existing drugs by leaving untreated those animals that are resilient to the infection (Malan *et al.*, 2001). The system is based on the fact that a characteristic symptom of haemonchosis is anaemia, which can be evaluated clinically by examination of the ocular mucous membranes with reference to a colour chart. Animals are then scored in one of five colour categories (from red, non-anaemic, to very pale, severely anaemic). Only those animals that require treatment are dewormed. The system was shown to have a test sensitivity of 76-85 % when tested with goats in South Africa (Vatta *et al.*, 2001).

The advantages of this system are that savings can be made in terms of anthelmintic use, the development of anthelmintic resistance should be slowed down and animals that repeatedly require treatment can be identified and culled from the flock or herd. The system should also complement the fact that the indigenous goats have already been naturally selected for hardiness over many years because of a lack of drug intervention. A great advantage of the system is that it is simple to comprehend and is equally applicable in commercial (Bath *et al.*, 2001) and small-scale farming systems (Vatta *et al.*, 2001; Vatta *et al.*, 2002a).

APPROACH ADOPTED IN THIS STUDY FOR THE TESTING OF APPROPRIATE SOLUTIONS

The FSR approach employed in this study was similar to that described by Collinson (1987) and consisted of diagnostic, planning, on-farm experimentation and assessment phases. In this approach, target groups of farmers are selected, problems are identified and research priorities are determined during the diagnostic phase. The farmers remain involved during the planning phase, when possible solutions are examined and ‘best bets’ chosen. Possible solutions are screened on-farm for ease of transfer (compatibility with agro-ecological and farm management conditions), system compatibility (compatibility with farmer priorities and resources) and economic attractiveness (*i.e.* potential profitability versus risk). After and during the planning

phase and still with the collaboration of the farmers, on-farm experimentation is carried out. This may be exploratory (e.g. to find ‘best bets’), be determinative (e.g. to determine whether possible solutions are compatible with agro-ecological and general farm management conditions) or be for verification (e.g. through wider replication of experiments). The final phase involves the development of recommendations, demonstration and extension with the farmers.

With respect to the present study, the initial diagnostic phase of identification of problems in the field was taken with the help of the local community and was carried out by the KwaZulu-Natal Department of Agriculture and Environmental Affairs (De Villiers and Letty, 2001). An on-station experiment was conducted at Onderstepoort (Fig. 1). Formulation of this experiment constituted part of the processes of ‘identification of best bets’ and screening for possible solutions to the identified problems, *i.e.* helminths, dry-season, winter feed shortages and poor reproductive capacity of goats. The experimentation on-station also provided the opportunity to test the various novel interventions for the control of disease without placing the participating farmers’ animals, and hence livelihoods, at any risk. Once the on-station experiment had been concluded and the scientific, economic and animal-safety aspects had been comprehensively assessed, an on-farm experiment was conducted in Bulwer to assess the recommendations of the on-station experiment under local agro-ecological and management conditions. To support the farmers’ expressed need for information on goat health and management, information in the form of a farmers’ goat health care manual was also packaged, tested with the farmers and revised for relevance, clarity and usefulness. Throughout the study there was local community involvement and information dissemination.

The study incorporated the application of the FAMACHA[®] system as a tool to identify and treat anaemic animals and investigated the use of protein supplementation, symptomatic and tactical anthelmintic treatments, and the interaction of these various interventions.

The specific protein supplement tested in this study was urea, incorporated in a urea-molasses block. This supplement was chosen by the researchers as it is a cheap product which is at least as readily available for purchase as anthelmintics. Tactical anthelmintic treatment and symptomatic treatment, according to the FAMACHA[®] system, were chosen as appropriate

chemotherapeutic options because, in the absence of suitable proven alternatives, anthelmintics must still form part of an integrated approach to helminth control. The apparent applicability of these anthelmintic treatment methods have been discussed above (see pages 14-15). The specific anthelmintic used, ivermectin, had been utilized in a previous study with good results and was therefore again used in the present study (Vatta *et al.*, 2001, 2002a).

While it was important to examine the individual effects of tactical and symptomatic anthelmintic treatment and nutritional supplementation on goat productivity in the target communities, another important aim was to examine the *interaction* between nutritional supplementation, drug treatment, gastrointestinal nematode infection and goat productivity. Information on this interaction was almost totally lacking and needed to be quantified.

The FSR methodology was adopted as it lent itself well to the testing of the nutritional, chemotherapeutic and farmer-educational approaches because, while it encouraged farmer participation, it also allowed for rigorous scientific evaluation of these interventions.

THESIS PRESENTATION

The remainder of this thesis is presented as follows:

- a. A published review paper entitled, 'Managing anthelmintic resistance in small ruminant livestock of resource-poor farmers in South Africa', which considers the problems of gastrointestinal nematode infection and anthelmintic resistance in domestic ruminants.
- b. A published paper entitled, 'Relative economic benefits of tactical anthelmintic treatment and urea-molasses block supplementation of Boer goats raised under extensive grazing conditions at Onderstepoort, Pretoria, South Africa'. This paper describes an on-station experiment to examine the interactions between nutritional and anthelmintic drug interventions.
- c. A published paper entitled, 'Benefits of urea-molasses block supplementation and symptomatic and tactical anthelmintic treatments of communally grazed indigenous goats in the Bulwer area, KwaZulu-Natal Province, South Africa'. This paper describes an on-farm experiment, conducted with the collaboration of a selected group of small-scale goat

farmers in the Bulwer area, KwaZulu-Natal Province, testing the best interventions identified in the on-station experiment under field conditions.

- d. A submitted paper entitled, 'Participation of Zulu farmers in a goat health research and extension project in South Africa'. This details the methods employed to engage the farming community, disseminate information and assess uptake, as well as the role taken by 'champion' farmers created through this process.
- e. The thesis is concluded by a general discussion and suggestions for future work.

Because the published papers are presented in their entirety in the thesis, some textual overlap between Chapter 1 and Chapters 2-5 was unavoidable. Please note that in respect of Chapters 2-4, some minor changes have been made to these published papers in order to ensure continuity throughout the thesis.

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Chapter 2

MANAGING ANTHELMINTIC RESISTANCE IN SMALL RUMINANT LIVESTOCK OF RESOURCE-POOR FARMERS IN SOUTH AFRICA

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ABSTRACT

Gastrointestinal parasitism is one of the most important disease complexes of sheep and goats impacting on the resource-poor livestock farmer. Of the responsible nematodes, *Haemonchus contortus*, a blood-sucking worm of the abomasum, poses possibly the greatest threat. Over the past several decades, the worm has been controlled through the use of anthelmintics, but the emergence of anthelmintic resistance has threatened this chemotherapeutic approach. In Africa, the overall prevalence of anthelmintic resistance has not been extensively investigated, particularly within the resource-poor farming sector, but resistance has been reported from at least 14 countries with most of the reports emanating from Kenya and South Africa and the majority concerning *H. contortus*. While levels of resistance under commercial sheep farming systems in South Africa is considered to be amongst the worst in the world, resistance has also been reported from the resource-poor farming sector. Increases in productivity and reproduction of livestock and the development of markets for sale of animals are seen by international funding bodies as a way out of poverty for communities that keep livestock. This must lead to the greater need for parasite control. At such times, the risk of levels of anthelmintic resistance escalating is much greater and there is therefore a need to look at alternatives to their use. Proposed strategies include the appropriate, but judicious use of anthelmintics by application of the FAMACHA® system and the use of alternatives to anthelmintics such as strategic nutrient supplementation. It is also very clear that there is a strong demand for knowledge about animal diseases, including helminthosis, and their effective management in the resource-poor livestock farming communities. This is an important challenge to meet.

Key words: Africa, anthelmintic resistance, goats, *Haemonchus contortus*, sheep, small ruminants.

INTRODUCTION

It is difficult to quantify the number of resource-poor livestock owners in South Africa. In the first instance, what is meant by resource-poor? A landless peasant who does not own animals would probably not consider a person that owns livestock to be resource-poor. On the other hand, comparing farmers within the South African community, one finds that there are very distinct differences in wealth between rural farming communities. These are most often distinguished along racial lines, but even within a particular community there are the resourced and less resourced farmers.

It is sobering to note that there is a rural population in South Africa of about 17.5 million people that are living below the rural poverty threshold (Table 6b, Thornton *et al.*, 2002). It cannot be accurately ascertained what proportion of these people are resource-poor farmers. However, Thornton *et al.* (2002) estimated that there were 10.6 million poor livestock keepers in South Africa. Of these, 3.5 million were living in mixed, rainfed, temperate production systems or tropical highlands; 3.1 million within mixed, rainfed, arid or semi-arid systems; 1.8 million within livestock only, rangeland-based arid or semi-arid systems (Table 7, Thornton *et al.*, 2002); and a further 1.2 million were to be found in mixed, rainfed, humid or subhumid systems. The remaining 1.1 million were estimated to be found in livestock-only, rangeland-based temperate or tropical highlands; mixed, irrigated, arid or semi-arid systems; mixed, irrigated, temperate or tropical highlands; livestock-only, rangeland-based, humid or subhumid systems; or other production systems.

A large number of resource-poor farmers in South Africa live in the previous 'homeland' areas (Krecek *et al.*, 1999; Gehring *et al.*, 2002). An official survey of large and small-scale agriculture indicated that in the year 2000 there were 614 000 farming operations in the former homelands of South Africa in contrast to 84 000 farming operations in the former Republic of South Africa (*i.e.* South Africa excluding the former homelands; Shabalala and Mosima, 2002). The farming operations of the homelands, designated for black Africans, were characterized by small-scale and subsistence farming while the farming operations of the former South Africa, designated for white-ownership, were mostly large-scale commercial operations.

If one assumes that each farming operation supported at least one household, and given that the average size of a household for South Africa is 3.8 persons (Anonymous, 2003), one may estimate that there are 2.3 million people dependent on small-scale and subsistence farming. This is a somewhat lower figure than that estimated by Thornton *et al.* (2002), but the figure nevertheless represents a sizeable number of people probably dependent on resource-poor farming.

In general terms, resource-poor livestock farmers will own only approximately ten animals. They have no security of land tenure and the animals are grazed communally. The communities are characterized by skewed demographics (high proportions of women, the aged and children) — a legacy of a history of migrant labour systems in South Africa. The people have poor access to facilities, information, infrastructure and finance, and in the case of resource-poor farmers within these communities, poor access to agricultural support services. As can be expected from all these negative factors, production and reproduction of livestock in these situations are low.

Resource-poor people often rely on a variety of sources of income, food and support (Chambers, 1997). This spreads the risk in the case of a particular income-generating activity failing. Of these various activities, animal production may be one of the most important, especially where lands for crop or vegetable production are marginal. Protein is an important component of the human diet and protein derived from animal sources fills a niche in the diet that is difficult to replace with vegetable products. In this regard, ruminants are especially important, being able to convert plant material that cannot be digested by humans into edible animal protein.

The most important helminth parasite of sheep and goats in the summer rainfall area of South Africa is *Haemonchus contortus*, both for the commercial and resource-poor farmer (Boomker *et al.*, 1994; Tsotetsi and Mbatia, 2003; Vatta *et al.*, 2001; Vatta *et al.*, 2002). Haemonchosis was recently ranked amongst the top ten diseases or pathogens affecting the animals of poor livestock farmers in eastern, central and southern Africa, while gastrointestinal parasitism was given the highest global index as an animal health constraint impacting on the poor (Perry *et al.*, 2002). *H. contortus* is a blood-sucking nematode found in the abomasum of small ruminants, posing a threat from about November to April when ambient temperature and rainfall are suitable for it to complete its life cycle on pasture. However, *H. contortus* may also be a threat in the cooler

months of the year and periodically causes problems in the semi-arid regions of the country in atypically wet years, as well as in the winter and non-seasonal rainfall areas.

AWARENESS OF GASTROINTESTINAL PARASITISM

Amongst resource-poor farmers, there appears to be a lack of understanding of the aetiology of disease, *e.g.* anaplasmosis is thought to be caused by ‘excessive grazing of lush green grass, which is thought to bring about an accumulation of bile in the body’ (Masika *et al.*, 1997a). In this example this may lead to treatment being ill directed at attempting to remove excessive bile from the animal’s body rather than correctly aimed at destroying the microorganisms concerned. Resource-poor farmers may use numerous ethnoveterinary medicines to prevent mortality and improve the health of their livestock. In many cases, these medications do have apparent rational and beneficial effects (Masika *et al.*, 1997a; Van der Merwe *et al.*, 2001; Getchell *et al.*, 2002). Resource-poor farmers also purchase commercial remedies when they are able to do so (Masika *et al.*, 1997a; Masika *et al.*, 1997b; Getchell *et al.*, 2002). However, the extent of their use of stock remedies is poorly documented in South Africa. Sales of anthelmintics for sheep and cattle and endectocides (all animal species) amounted to more than 117 million rand in 2003/2004 (South African Animal Health Association market statistics, A du Plessis, pers. comm., 2004), but most of these sales were probably to the commercial farming sector.

It was the experience of Van Wyk *et al.* (1999) that resource-poor farmers in the former Lebowa (in Mpumalanga and Limpopo Provinces) did not consider internal parasites important possibly because of their location inside the hosts and their generally small size. Many farmers also appeared not to be aware of the existence of internal parasites and their treatment was therefore given a low priority. This is contrasted with certain farmers in the Bulwer area of KwaZulu-Natal who purchase commercial deworming remedies (B A Letty, KwaZulu-Natal Department of Agriculture and Environmental Affairs, pers. comm., 2002).

There appears to be a greater awareness of tapeworms than of the more dangerous roundworms (Getchell *et al.*, 2002). This is probably because the tapeworm proglottids are visible with the naked eye on the dung of the animal. The women, who are traditionally tasked with the

preparation of food, may be more likely to notice nematodes in the gastrointestinal contents but may not appreciate their importance (A F Vatta, pers. obs., 2002). Even then many of the nematodes may be missed because of their small size – several species are only visible under a microscope. The perceived lack of understanding of the importance of gastrointestinal roundworms is also demonstrated by an apparent lack of common names for the various nematodes in the indigenous languages of South Africa. Contrast this, for example, with common names for *Haemonchus contortus* and *Trichostrongylus* spp. which are respectively called wireworm and bankruptworm in English and *haarwurm* and *bankrotwurm* in Afrikaans.

PREVALENCE OF ANTHELMINTIC RESISTANCE

In farming systems where helminth control relies exclusively on the use of anthelmintics, the emergence of resistance to such compounds poses a severe threat to livestock production. This is of particular concern where a strain is resistant to drugs in more than one or all anthelmintic groups available on the market. In Africa, anthelmintic resistance has been reported in sheep and/or goats from at least 14 countries (Fig. 1). By far the most reports have emanated from Kenya and South Africa and the majority of these concern *Haemonchus* spp. There is a lack of detailed background information for some of the reports listed in Fig. 1, but it appears that the vast majority of the papers (52 out of the 63 cited) are from large-scale commercial or institutional farms. Six of the reports concern small-scale or resource-poor farms while five deal with both large and small farming enterprises. In South Africa, anthelmintic resistance in the commercial sheep farming sector has been described as being the worst in the world (Van Wyk *et al.*, 1999). In resource-poor systems in South Africa, resistance has been reported in sheep in one study (Van Wyk *et al.*, 1999) and in goats in another two studies (Bakunzi, 2003; Vatta *et al.*, 2001).

The overall prevalence of resistance in Africa has, however, not been extensively investigated and this is particularly so in the resource-poor context. Survey work for anthelmintic resistance is hampered, among other things, by the lack of readily available assays. The faecal egg count reduction test, which is the most commonly used test, requires the use of a relatively large

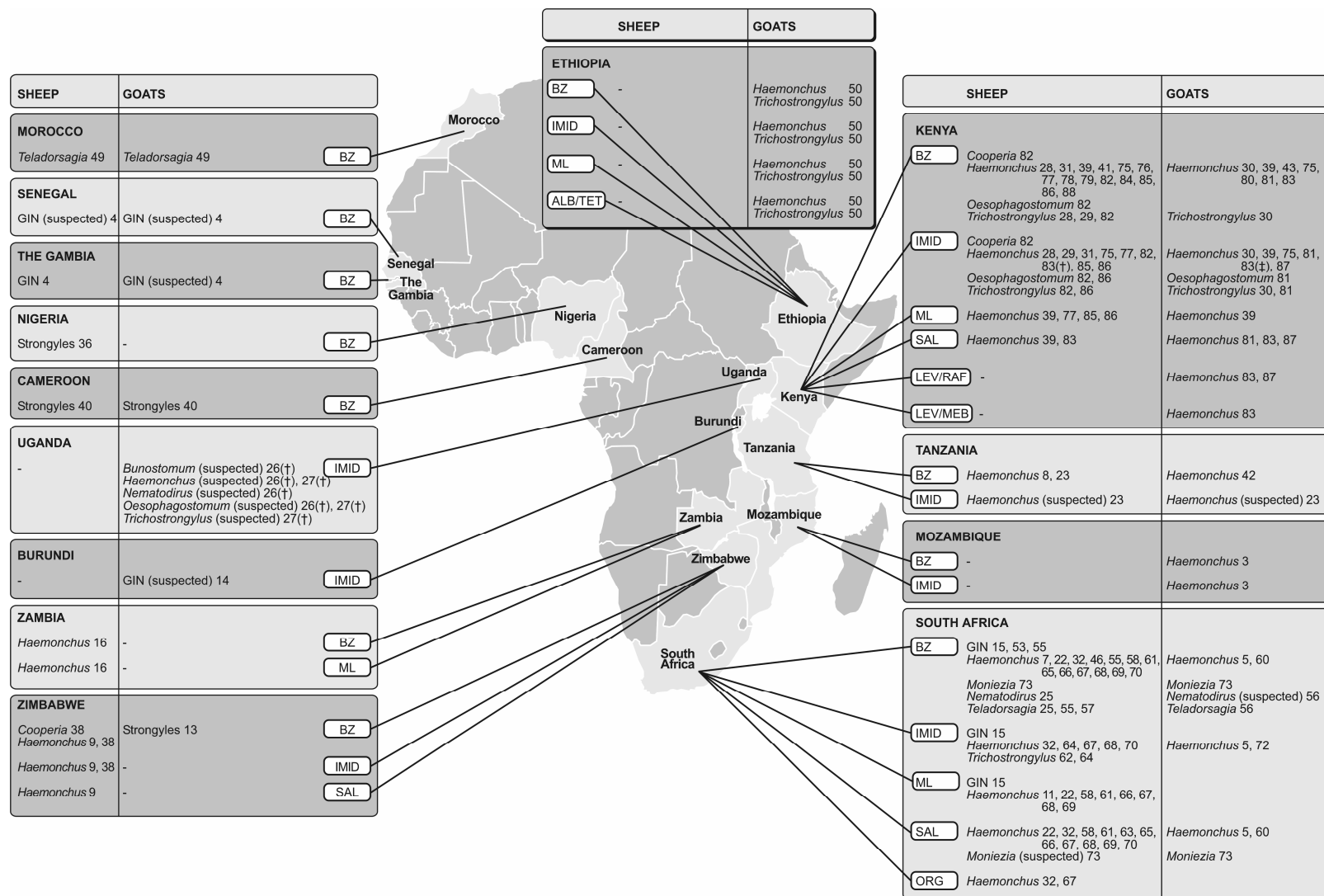


Fig. 1: Reports of anthelmintic resistance in helminths of sheep and goats in Africa. Some studies are laboratory confirmations or repeat investigations of previously published reports. Where the original reports referred to *Ostertagia*, these are reflected as *Teladorsagia* in the figure above

Key to Fig. 1:

GIN: gastrointestinal nematodes; BZ: benzimidazoles and pro-benzimidazoles; IMID: imidazoles; ML: macrocyclic lactones; SAL: halogenated salicylanilides and nitrophenols; ORG: organophosphates; ALB/TET: albendazole-tetramisole combination; LEV/RAF: levamisole-rafoxanide combination; LEV/MEB: levamisole-mebendazole combination; † products considered possibly substandard, adulterated or fake; ‡ one levamisole product considered substandard; true resistance found to a second product

References for Fig. 1:

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|----|---------------------------------------|----|------------------------------------|
| 3 | Atanásio <i>et al.</i> (2002) | 55 | Van Schalkwyk (1984) |
| 4 | Bâ and Geerts (1998) | 56 | Van Schalkwyk and Schröder (1989) |
| 5 | Bakunzi (2003) | 57 | Van Schalkwyk <i>et al.</i> (1983) |
| 7 | Berger (1975) | 58 | Van Wyk (1990) |
| 8 | Bjørn <i>et al.</i> (1991) | 60 | Van Wyk and Gerber (1980) |
| 9 | Boersema and Pandey (1997) | 61 | Van Wyk and Malan (1988) |
| 11 | Carmichael <i>et al.</i> (1987) | 62 | Van Wyk <i>et al.</i> (1990) |
| 13 | Chavunduka (1970) | 63 | Van Wyk <i>et al.</i> (1982) |
| 14 | Dacasto and Cocuzza (1995) | 64 | Van Wyk <i>et al.</i> (1989a) |
| 15 | Dreyer (2002) | 65 | Van Wyk <i>et al.</i> (1987) |
| 16 | Gabriel <i>et al.</i> (2001) | 66 | Van Wyk <i>et al.</i> (1989b) |
| 22 | Jeannin <i>et al.</i> (1990) | 67 | Van Wyk <i>et al.</i> (1997) |
| 23 | Keyyu <i>et al.</i> (2002) | 68 | Van Wyk <i>et al.</i> (1999) |
| 25 | Louw and Reinecke (1993) | 69 | Van Wyk <i>et al.</i> (1991) |
| 26 | Magona and Musisi (1999) | 70 | Van Wyk <i>et al.</i> (1989c) |
| 27 | Magona <i>et al.</i> (2000) | 72 | Vatta <i>et al.</i> (2001) |
| 28 | Maingi (1991a) | 73 | Visser <i>et al.</i> (1987) |
| 29 | Maingi (1991b) | 75 | Wanyangu <i>et al.</i> (1996) |
| 30 | Maingi (1993) | 76 | Waruiru (1994) |
| 31 | Maingi <i>et al.</i> (1998) | 77 | Waruiru (1997a) |
| 32 | Malan <i>et al.</i> (1990) | 78 | Waruiru (1997b) |
| 36 | Mbah <i>et al.</i> (1992) | 79 | Waruiru (1998) |
| 38 | Mukaratirwa <i>et al.</i> (1997) | 80 | Waruiru (2002) |
| 39 | Mwamachi <i>et al.</i> (1995) | 81 | Waruiru <i>et al.</i> (1998a) |
| 40 | Ndamukong and Sewell (1992) | 82 | Waruiru <i>et al.</i> (1991) |
| 41 | Ndarathi (1992) | 83 | Waruiru <i>et al.</i> (1998b) |
| 42 | Ngomuo <i>et al.</i> (1990) | 84 | Waruiru <i>et al.</i> (1994) |
| 43 | Njanja <i>et al.</i> (1987) | 85 | Waruiru <i>et al.</i> (1997) |
| 46 | Reinecke (1980) | 86 | Waruiru <i>et al.</i> (1998c) |
| 49 | Silvestre <i>et al.</i> (2002) | 87 | Waruiru <i>et al.</i> (2003) |
| 50 | Sissay <i>et al.</i> (2006) | 88 | Waruiru <i>et al.</i> (1996) |
| 53 | Van den Hever and Van Straaten (1989) | | |

number of animals, something which is rarely available in smallholder systems. It is also time-consuming and hence costly. The *in vitro* larval development assay has been adapted to the smallholder setting (Ancheta *et al.*, 2004), but it requires specific training, kits and equipment that are not in place in South Africa at present.

DEVELOPMENT AND SPREAD OF ANTHELMINTIC RESISTANCE

The highly effective chemotherapeutic control of pest organisms (in this case nematodes) and preservation of drug efficacy are unfortunately mutually exclusive objectives. The gene or genes conferring anthelmintic resistance are thought to be present in a small portion of individuals in the population even before the worms are exposed to a drug for the first time (Jackson, 1993). Treatment with anthelmintics then selects for those individuals within a population that are resistant to the drug.

Van Wyk (2001) has drawn attention to the importance of the role *refugia* play in the development of anthelmintic resistance. *Refugia* refer to the proportion of a parasite population that is not exposed to anthelmintics during any one treatment *e.g.* nematode larval stages on pasture, thus escaping selection for resistance (Michel, 1985) and potentially able to propagate its genes to the next generation. Treatments carried out when there are few worms *in refugio* are likely to select strongly for resistance.

As stated above, most of the reports of anthelmintic resistance are from large-scale commercial or institutional farms. Under these conditions, the selection pressure for anthelmintic resistance is often intense with, for example, frequent anthelmintic treatment of the whole herd. This in itself exposes a greater proportion of the nematode population to anthelmintics and leaves fewer worms *in refugio* than would be the case, for example, if only those individual animals showing signs of helminthosis were drenched. The frequent use of anthelmintics increases the frequency with which individual nematodes and their offspring are exposed to anthelmintics as well as the probability that a nematode will be exposed to an anthelmintic within a certain period of time. Large herd size has been reported as a risk factor for the presence of resistance (Wanyangu *et al.*, 1996). Farmers with large flocks are more likely to be able to buy anthelmintics.

Conversely, farmers with smaller flocks often cannot afford to buy anthelmintics and this may serve to slow down the onset of resistance (Wanyangu *et al.*, 1996). In South Africa, access to anthelmintics may also be difficult even for those who want to treat because of sparsely distributed agricultural co-operatives and size of packaging, which is generally too large for the number of animals that need to be treated (Gehring *et al.*, 2002). (In the South African context, ...

[agricultural co-operatives are] stores which sell stock remedies such as dewormers and dips, seed, agricultural implements, protective clothing and fertilisers.) This should also be seen in the context of other more important priorities such as access to water, hospital care and schools (Getchell *et al.*, 2002).

Nevertheless, anthelmintic resistance has been reported from the small-scale and resource-poor sector. Although anthelmintics may be used more sparingly by smallholder and resource-poor farmers than large-scale commercial farmers, the emergence of resistance in this sector has also been attributed to the prolonged use of drugs from the same class of anthelmintic (Maingi *et al.*, 1998; Magona *et al.*, 2000; Atanásio *et al.*, 2002; Bakunzi, 2003) and frequent treatment of flocks (Magona *et al.*, 2000; Wanyangu *et al.*, 1996; Bakunzi, 2003).

Various authors speculate that the occurrence of anthelmintic resistance in a flock/herd resulted from the introduction of resistant worms from other flocks/herds. This may have been through the sale or distribution of stock (together with their resistant worms) from larger commercial or government-owned farms to smaller farms (Wanyangu *et al.*, 1996; Van Wyk *et al.*, 1999; Vatta *et al.*, 2001; Bakunzi, 2003); through the introduction of stock from other farms (where no mention of size of farm is made; Maingi *et al.*, 1998; Atanásio *et al.*, 2002); through the appropriation of farms from commercial farmers and addition to existing communal pastures (Van Wyk *et al.*, 1999); and through communal grazing (Magona and Musisi, 1999; Silvestre *et al.*, 2002). Sissay *et al.* (2006), on the other hand, exploited the apparent lack of anthelmintic resistance in communally grazed smallholder flocks to reverse to susceptibility the resistant status of a university goat flock.

Whether resistance develops on resource-poor smallholdings would depend on the numbers of imported worms in relation to the existing worm population and on the resulting frequency of worms with resistant genes. The further development will also depend on the way anthelmintics are used by the smallholder farmers. If, for example, the introduction of animals with resistant worms to a flock occurs and the whole flock is drenched with the same active to which there is resistance in the flock from which the animals were introduced and the drenching is carried out at frequent intervals and/or at times when there are few worms *in refugio*, the chances of resistance developing

are higher than in cases where drenching of the herd occurs very infrequently [as was reportedly the case in the investigation by Sissay *et al.* (2006)].

Other reasons given for the development of resistance under these farming conditions include underdosing by incorrect estimation of weights (Magona and Musisi, 1999; Maingi *et al.*, 1998); ‘underdosing as a result of limited financial resources’ (Bakunzi, 2003); and the use of sheep dosages in goats (Magona and Musisi, 1999; Wanyangu *et al.*, 1996). Van Wyk (2001) argues that it is not underdosing *per se* that is necessarily responsible for the development of the resistance but that development of resistance is probably related to the elimination through drenching of ‘all but the most resistant individuals combined with low numbers of worms *in refugio*’ (Van Wyk, 2001).

The use of expired products (Atanásio *et al.*, 2002) and the use of substandard products (Magona and Musisi, 1999; Magona *et al.*, 2000) make it difficult to determine whether anthelmintic failure is as a result of resistance or inactivity of the product (Wanyangu *et al.*, 1996).

ALTERNATIVES TO ANTHELMINTICS IN THE CONTROL OF GASTROINTESTINAL PARASITISM

If management and productivity of small ruminants are improved in line with the global visions of internationally funded research bodies (Perry *et al.*, 2002), helminths will need to be managed. Unless other methods of parasite control are available, this will call for an increased use of anthelmintics, which, in turn, is the driving force for the development of anthelmintic resistance. If resistance is already present, this potential pathway out of poverty will be severely hampered. The farmer therefore needs to be making the best use of the drugs now so that their efficacy is maintained for as long as possible, and also to find alternative and complementary ways of controlling gastrointestinal parasites.

Other options that have been considered as alternatives to the sole reliance on anthelmintics for parasite control include the better use of existing drugs, for example by combining the use of drugs with grazing strategies, vaccines, copper oxide wire particles, biological control through, for example, nematophagous fungi, nutrient supplementation (Waller, 1999), breeding of host animals for worm resistance (Gray, 1997), ethnoveterinary medicine

(Githiori *et al.*, 2002) and tanniferous plants and extracts (Paolini *et al.*, 2003). Many of these approaches are still being researched and evaluated and most of them are at present not suitable for the communal grazing systems of many resource-poor farmers. For example, the adoption of a common grazing strategy would require a community effort, which would currently be difficult to achieve in a communal grazing system. There are two possible interactions that would be of assistance to the resource-poor farmer and go some way towards achieving sustainable parasite control. These are the use of the FAMACHA[®] system and nutritional supplementation.

The FAMACHA[®] system

This is a method of targeted treatment and is a strategy for conserving the efficacy of existing drugs (Malan *et al.*, 2001). The system is based on the fact that sheep and goats suffering from haemonchosis show varying degrees of anaemia, which can be evaluated clinically by examination of the ocular mucous membranes. With the help of a colour chart, animals are scored in one of five colour categories (from red, non-anaemic, to very pale, severely anaemic). Only those animals in need of treatment are treated.

The advantages of such a system are that savings can be made in terms of anthelmintic use, the development of drug resistance should be slowed down and animals that repeatedly require treatment can be identified and culled from the flock or herd. The system should also complement the fact that resource-poor people often already have animals that have been naturally selected for hardiness over many years because of a lack of drug intervention. A great advantage of the system is that it can be easily understood and learnt by poorly literate people. This has been demonstrated on commercial farms (Bath *et al.*, 2001), where the system has found great acceptance, and in resource-poor farming systems (Vatta *et al.*, 2001; Vatta *et al.*, 2002).

Nutritional supplementation

Nutritional or micronutrient deficiencies in livestock have also been ranked highly in terms of their importance to the resource-poor farmer (Perry *et al.*, 2002). In resource-poor areas of South Africa, dry-season hunger, as elsewhere in southern Africa, is a very important constraint to animal

production. Relatively cheap supplements such as non-protein nitrogen, in liquid form for mixing with poor quality roughages or formulated into blocks or granules, are alternatives, but accessibility may similarly be hampered as for anthelmintics. To overcome this limitation, local forages are being examined as dry-season supplements. In Zimbabwe, supplementation of does with seed pods of local browse trees ... [has been investigated (Sikosana *et al.*, 2004)].

EDUCATION

Perhaps education is the principal requirement for assisting resource-poor farmers to improve the health, productivity and welfare of their animals. Without knowledge, the resource-poor farmer cannot improve herd management and prophylaxis of disease by means of vaccination. Knowledge is required to be able to recognize the importance of specific disease conditions and circumstances favouring their development, for instance a greater awareness of the presence and pathogenic effects of nematodes, the epidemiological conditions that are optimal for their survival, and how to manage the infections for the long-term.

CONCLUSION

Anthelmintics will remain an important part of the management of worm infections, but they need to be used in a sustainable manner. Particularly in the resource-poor sector of South Africa, where the level of anthelmintic resistance appears to be at a lower level than that on large-scale farms (Van Wyk *et al.*, 1999), the opportunity exists to slow the development of resistance. The best way forward must be education, and the opportunity now exists to build the control of gastrointestinal parasites on measures other than only anthelmintic treatment.

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Chapter 3

RELATIVE ECONOMIC BENEFITS OF TACTICAL ANTHELMINTIC TREATMENT AND UREA-MOLASSES BLOCK SUPPLEMENTATION OF BOER GOATS RAISED UNDER EXTENSIVE GRAZING CONDITIONS AT ONDERSTEPSPOORT, PRETORIA, SOUTH AFRICA

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ABSTRACT

The potential economic benefits of combining tactical anthelmintic treatment for gastrointestinal nematodes and nutritional supplementation with urea-molasses blocks were examined in Boer goats raised under extensive grazing conditions in the summer rainfall area of South Africa. Eight groups of nine goats were monitored over a 12-month period from 1 October 2002 to 9 October 2003. *Ad libitum* nutritional supplementation with urea-molasses blocks was provided when the goats were housed at night, during the summer (wet season – December 2002 to February 2003), and / or the winter (dry season – June 2003 to August 2003). All the goats were treated symptomatically for *Haemonchus contortus* infection when deemed necessary by clinical examination of the conjunctiva for anaemia using the FAMACHA[®] system. Half the groups were tactically treated for gastrointestinal nematodes in mid-summer (28 January 2003). Under the symptomatic treatment, climatic and extensive grazing conditions encountered during the trial, feed supplementation in the winter dry season had the greatest economic benefit and is therefore recommended. Tactical anthelmintic treatment afforded no additional advantage, but the nematode challenge was low.

Keywords: Boer goats, extensive grazing, *Haemonchus contortus*, symptomatic drenching, tactical drenching, urea-molasses blocks.

INTRODUCTION

Livestock disease caused by gastrointestinal nematodes is considered to have a major impact on the livelihoods of poor livestock keepers (Perry *et al.*, 2002). The use of anthelmintics is currently the most common method of parasite control, but the continuing emergence of anthelmintic resistance seriously threatens long-term efficacy. Protein supplementation has been identified as an alternative approach in the management of nematodes (Coop and Kyriazakis, 1999). Therefore, the aim of the current study was to obtain quantitative data on the economic benefits of tactical anthelmintic treatment combined with nutritional supplementation against gastrointestinal nematode infections in Boer goats. Here we define tactical anthelmintic treatment as the deworming of an entire flock when a large number of worms are expected (e.g. after good rains at a time when temperature and pasture conditions are ideal for the free-living stages) (Van Schalkwyk *et al.*, 1995) and symptomatic treatment as the specific treatment of individual animals showing life-threatening clinical signs of worm infection.

MATERIALS AND METHODS

Climate data

The experiment ran from 1 October 2002 to 9 October 2003. Rainfall data were obtained from records kept on the Onderstepoort Veterinary Institute's (OVI's) experimental farm situated near Pretoria for the years 1991 to 2003. Temperature data for Pretoria were obtained from the South African Weather Service.

Parasites and infection of goats

Haemonchus contortus third-stage nematode larvae (L₃) of an anthelmintic-susceptible population (Moredun population) were obtained from the OVI bank of nematode larvae which are preserved in liquid nitrogen. Just prior to use, required numbers of cryopreserved larvae were thawed in lukewarm water. Their motility was checked and their density was adjusted to *ca.* 1 000 L₃/ml with tap water. They were kept in suspension by agitating their container. The

goats were orally infected by slowly depositing the required amount of L₃ suspension over the base of the tongue with the use of a plastic syringe, to ensure that all the infective larvae would be swallowed.

Animal maintenance

Seventy-two 5 to 6 month old male Boer goats were purchased from the Kuruman district, Northern Cape Province, South Africa and transported to Onderstepoort Veterinary Institute near Pretoria in two batches during June and July 2002. They were housed in pens with concrete floors, which were cleaned daily from Monday to Friday. Intact goats were castrated. All were fed a commercial pelleted feed and hay and water *ad libitum*. As set out in Table 1, the animals were dewormed and artificially re-infected with ca. 3 000 third-stage larvae of *H. contortus*.

Table 1: Anthelmintic treatments administered to experimental Boer goats prior to artificial infection with *Haemonchus contortus* in preparation for the experiment

Date	Time of day	Treatment
17 July 2002	Morning	7.5 mg/kg oxfendazole (Oxfen™, Bayer Animal Health)
18 July 2002	Morning	5.0 mg/kg oxfendazole (Oxfen™, Bayer Animal Health)
18 July 2002	Afternoon	5.0 mg/kg oxfendazole (Oxfen™, Bayer Animal Health)
19 July 2002	Morning	12.0 mg/kg levamisole (Tramisol™, Intervet)
30 or 31 July 2002		Faecal flotations ^a positive for 23 of 72 goats
7 to 13 August 2002	Morning	400 µg/kg ivermectin (Ivomec Liquid™, Merial South Africa)
19 August 2002		Faecal flotations negative for all goats
23 August 2002		Infection with ca. 3 000 third-stage larvae of <i>H. contortus</i> ¹
26 August 2002		Transfer to experimental paddocks

^a Flat-sided medicine bottle flotation method (Reinecke, 1983).

On 26 August 2002, the animals were moved to the Onderstepoort Veterinary Institute's experimental farm ("Kaalplaas"), where they grazed extensively in a paddock of ca. 110 ha of mixed grazing and browse. The pasture had apparently not been grazed by small ruminants for 6

¹ Three millilitres of a larval suspension with a density of 1 000 L₃/ml was administered to each goat.

years prior to the current study, but had been used for the grazing of cattle, which shared the paddock with a small number of impalas (*Aepyceros melampus*), common duikers (*Sylvicapra grimmia*), steenbok (*Raphicerus campestris*) and warthog (*Phacochoerus aethiopicus*). The cattle were removed from the paddock before the start of the experiment.

Experimental design and monitoring

On 1 October 2002 the goats were allocated to eight groups each comprising nine animals (Table 2). The groups were balanced for live weight. This was done as follows: the goats were ranked in terms of live weight from highest to lowest live weight as determined on 25 September 2002. The eight goats with the highest live weights were then each randomly allocated to a group. The next eight goats were similarly randomly allocated to a group. This process was followed until all the goats had been allocated to a group. The goats were housed in sheds per feed group at night when urea-molasses block supplementation [Voermol Protein Blocks, Maidstone, South Africa; urea 67 g/kg dry matter (DM)] was provided *ad libitum* to the supplemented groups during the appropriate periods. About 10 kg of a commercially prepared pelleted feed (crude protein 174 g/kg DM) was scattered in the feed troughs each evening to lure the animals back into the sheds and its effect on the animals' nutrition was considered negligible. The goats were monitored throughout the experimental period and on 28 January 2003 some were either treated tactically with 400 µg/kg ivermectin administered orally, while others were not.

The goats were examined for anaemia according to the FAMACHA[®] system on a weekly basis (Vatta *et al.*, 2001)². The FAMACHA[®] system allows the animal's mucous membrane colour to be classed into one of five colour categories from 1 (non-anaemic) to 5 (severely anaemic). Symptomatic anthelmintic treatments with ivermectin (Ivomec Liquid™, Merial South Africa, 400 µg/kg) were given orally to those animals scored in Categories 3, 4 or 5, as these levels of

² The goats were examined for anaemia by means of the FAMACHA[®] system, weighed and body condition scored and samples were collected from them for faecal egg count and blood analyses on a weekly basis from 27 August 2002 onwards. However, the statistical analyses were only carried out on the data from 1 October 2002 onwards, when the goats had been allocated to their respective groups.

Table 2: A comparison of the market value per goat corrected as applicable for the costs of supplementation with urea-molasses blocks and tactical ivermectin treatment for gastrointestinal nematodes for eight groups of nine Boer goats. Each group was either tactically treated on 28 January 2003 (+) or not (-). All the goats were treated symptomatically with ivermectin as and when required. Supplementation with urea-molasses blocks was either not given or given in the dry winter season (June to August 2003), the wet summer season (December 2002 to February 2003), or both periods

Group	Time of urea-molasses block supplementation	Tactical ivermectin treatment	Mean dressed-out carcass weight (kg)	Market value ^a	Cost of urea-molasses blocks per animal	Cost of ivermectin treatment per animal	Mean net value per animal	Net benefit over Group 1 controls
1	Unsupplemented	-	25.0	54.98	0	0	54.98	0
2	Unsupplemented	+	24.4	53.61	0	0.69	52.92	-2.06
3	Dry season	-	27.6	60.79	2.51	0	58.28	3.30
4	Dry season	+	25.1	55.13	2.51	0.68	51.94	-3.04
5	Wet season	-	23.1	50.91	2.15	0	48.76	-6.22
6	Wet season	+	23.5	51.68	2.15	0.69	48.84	-6.14
7	Wet and dry seasons	-	23.8	52.43	4.66	0	47.77	-7.21
8	Wet and dry seasons	+	25.4	55.79	4.66	0.71	50.42	-4.56

All prices are stated in US\$. (US\$ 1.00 was approximately equal to R7.00 in January 2004).

^a The market value of the carcass was estimated at US\$ 2.20/kg.

anaemia are considered to be life-threatening.

On the same day that the goats were examined clinically for anaemia, they were weighed and scored for body condition. Faecal samples were collected to determine nematode egg counts (Reinecke, 1983) and faecal cultures were prepared in order that differential third-stage nematode larval counts could be made (Reinecke, 1983; Van Wyk *et al.*, 2004). However, the infective larvae of *Teladorsagia* and *Trichostrongylus* spp. were not differentiated. Blood was collected in tubes containing EDTA (Vacutainer™ tubes, Becton Dickinson, France) for haematocrit determination (Vatta, 2001) and in tubes for serum analyses for total protein, albumin and urea. Serum total protein, albumin and urea were determined by means of colorimetric methods utilizing reflectance spectrophotometry (Vitros™, Johnson and Johnson Clinical Diagnostics).

The study ran until 9 October 2003, when the animals were slaughtered, their dressed-out carcass weights determined and their nematodes recovered from the abomasum, small intestine, and caecum and colon following the methods of Van Wyk *et al.* (1987), Visser *et al.* (1987) and Wood *et al.* (1995).

Economic analysis

The most economically viable experimental treatment was determined by cost-benefit analysis (Table 2). The mean cold dressed-out carcass weight was determined for each group of goats and was multiplied by US\$ 2.20/kg, the market value per kilogram of meat at slaughter, to give the mean market value per carcass for each group. The calculation of the cost of urea-molasses block supplementation per goat was based on the amount of urea-molasses block consumed per goat per group, where applicable, and the cost of a urea-molasses block at purchase. This assumed that each goat consumed the same amount of block, which is not usually the case. The cost of the tactical treatment per goat, where applicable, was calculated by determining the average amount of anthelmintic drenched per goat for that group and multiplying this value by the cost of anthelmintic at purchase. The costs of block supplementation and tactical treatment were then subtracted from the mean market value per carcass where applicable, and the corrected carcass value subtracted

from the mean market value per carcass for Group 1. The resultant value indicated an increase or decrease in carcass value relative to Group 1.

Herbage sampling

With the exception of the week of 23 to 29 December 2002, herbage samples were collected weekly from 31 October 2002 to 2 October 2003. These were collected by cutting or plucking the grass and herbs falling within a quadrat of 400 mm x 400 mm thrown at random on ten occasions during a walk-about [the method having been modified from that described by Smith (1999) for sward sampling]. The walk-about took the form of a route in the shape of a “W”, “X” or variation thereof within the paddocks grazed by the goats and was similar to the collecting route described by Hansen and Perry (1994) for isolating infective larvae from herbage. Six different routes were followed in rotation. During each walk-about, samples of browse leaves were also collected from shrubs falling within *ca.* 3 m of the place where the quadrat fell. The samples were air-dried, coarsely milled to a diameter of *ca.* 10 mm before being further milled through a 1 mm sieve in the laboratory and analysed for dry matter (Harris, 1970), ash (Harris, 1970), acid detergent fibre (Goering and Van Soest, 1970) and neutral detergent fibre (Robertson and Van Soest, 1981). Crude protein content was determined by the Dumas combustion method using the Leco FP-2000 instrument (Leco Corporation, St Joseph, Michigan, USA).

Data handling and analysis

The data were analysed statistically by means of a 2 x 4 factorial analysis of variance, testing both the main effects of tactical anthelmintic treatment and supplementary feeding and the treatment by feeding interaction. Means were separated using Fisher's protected t-test least significant difference (LSD) at the 5 % level. All data were analysed using the GenStat statistical system (GenStat® for Windows™ 7th edition, VSN International Ltd). The data for the faecal egg counts and worm counts were log₁₀-transformed for analysis to stabilize variances but the untransformed data is presented in the figures.

RESULTS

Rainfall and temperature

For the purposes of this experiment, summer is defined as running from 1 December to 28 February and winter from 1 June to 31 August. It was unusually dry in November 2002 (Fig. 1), and there was no rainfall from April to September 2003.

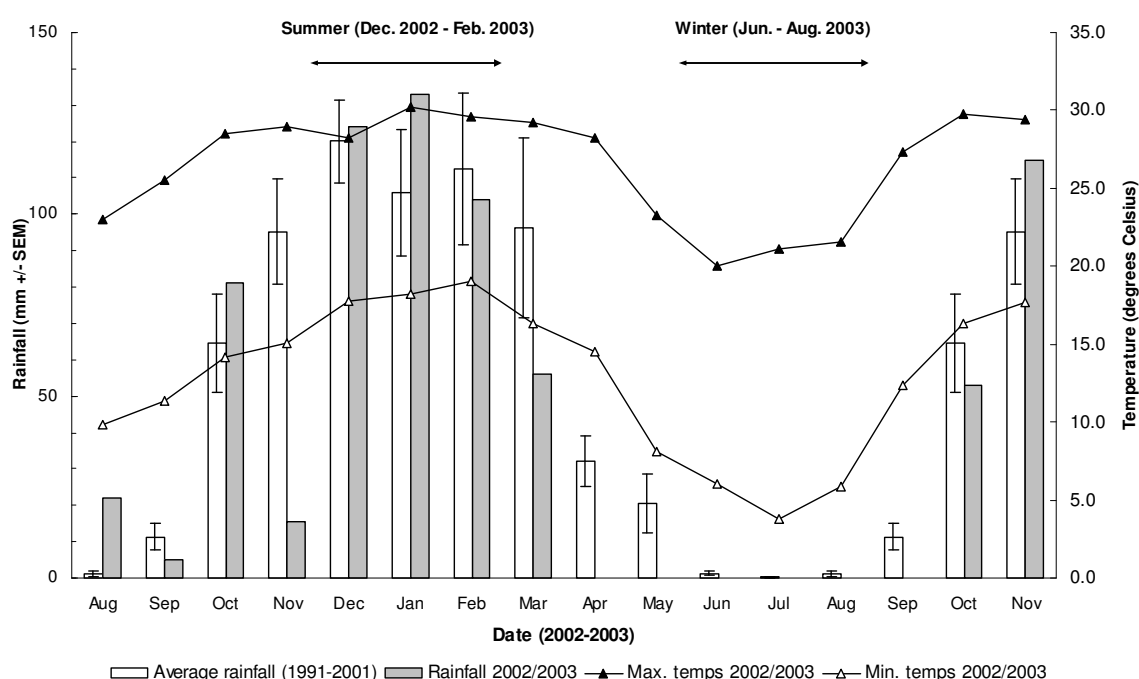


Fig. 1: **The rainfall** (compared with the average for 1991-2001 \pm the standard error of the mean) **and temperature data for the Onderstepoort Veterinary Institute's experimental farm during the experimental period**

Herbage analysis

The average composition of the herbage samples collected throughout the period of the experiment is given in Table 3. The dry matter content of the herbage was lowest during the period of summer rainfall and increased in the dry winter season (Table 4). The crude protein content of the herbage was highest in the rainy season and decreased as the grazing matured (Table 4). The acid detergent fibre and neutral detergent fibre content remained relatively consistent throughout the period of the experiment (data not shown).

Table 3: Average composition of herbage sampled weekly from 31 October 2002 to 2 October 2003 in the paddocks where the goats were grazed for the experiment

Herbage samples	Dry matter (g/kg)	Moisture content (g/kg)	Crude protein (g/kg DM)	ADF (g/kg DM)	NDF (g/kg DM)	Ash (g/kg DM)
Mean	578	422	69	361	592	101
SD	122	122	15	24	42	12
SEM	18	18	2	4	6	2
Minimum	328	207	45	307	508	81
Maximum	793	672	107	409	666	139
<i>n</i>	48	48	48	48	48	47

SD: standard deviation.

SEM: standard error of the mean.

DM: dry matter.

ADF: acid detergent fibre.

NDF: neutral detergent fibre.

Table 4: Seasonal mean pasture dry matter (DM), pasture crude protein (CP), body condition score, total serum protein, serum albumin, serum urea and haematocrit for spring 2002 (1 October to 30 November 2002), summer 2002/03 (1 December 2002 to 28 February 2003), autumn (1 March to 31 May 2003), winter (1 June to 31 August 2003) and spring 2003 (1 September to 9 October 2003)

	Spring 2002	Summer 2002/03	Autumn 2003	Winter 2003	Spring 2003
Mean pasture DM \pm SD (g/kg)	519 \pm 75	462 \pm 71	551 \pm 100	709 \pm 50	650 \pm 99
Mean pasture CP \pm SD (g/kg DM)	76 \pm 9	82 \pm 10	68 \pm 9	54 \pm 9	72 \pm 20
Mean body condition score \pm SD	2.0 \pm 0.3	2.6 \pm 0.4	3.3 \pm 0.5	3.1 \pm 0.5	2.8 \pm 0.5
Mean total serum protein \pm SD (g/l)	63.5 \pm 3.4	65.2 \pm 3.2	64.4 \pm 3.4	64.6 \pm 4.1	64.3 \pm 3.2
Mean serum albumin \pm SD (g/l)	24.9 \pm 1.9	26.3 \pm 2.1	27.1 \pm 2.5	25.1 \pm 1.9	26.1 \pm 1.8
Mean serum urea \pm SD (mmol/l)	5.55 \pm 1.23	5.91 \pm 1.41	4.71 \pm 1.32	2.59 \pm 1.01	2.06 \pm 0.61
Mean haematocrit \pm SD (%)	23.8 \pm 2.1	24.2 \pm 2.3	25.3 \pm 2.3	25.5 \pm 2.4	25.2 \pm 2.2

SD: standard deviation.

Consumption of blocks

The consumption of block per goat per day for the wet summer season supplementation period was estimated at 54 g (wet-season-supplemented group) and 62 g (wet-and-dry-season-supplemented group). During the dry winter season, the consumption per goat per day was 78 g (dry-season-supplemented group) and 77 g (wet-and-dry-season-supplemented group). The intake of block was lower than the manufacturer's recommended daily intake of 100-140 g per sheep per day (Voermol Pasture Supplements Product Handbook, 2nd edition, Voermol, Maidstone, South Africa).

Parasitological findings

While the goats were infected with *H. contortus* (Fig. 2), the egg counts were low throughout the study [< 400 eggs per gram of faeces (epg)]. Before tactical treatment, there were no statistically significant differences in mean egg counts between tactically and non-tactically treated groups. The tactical treatment was effective ($P < 0.001$), with the mean egg count dropping to almost zero in the tactically treated groups. There were generally no statistically significant differences between mean egg counts for the feed groups. After May 2003, all the groups had very low egg counts (< 150 epg).

Third-stage larvae of *Haemonchus* spp. predominated in the faecal cultures from October 2002 to March 2003. During April and May 2003 larvae of *Haemonchus* and *Teladorsagia* / *Trichostrongylus* spp. occurred in approximately equal numbers in the cultures, while from June to October 2003 larvae of *Teladorsagia* / *Trichostrongylus* spp. were predominant (data not shown). Larvae of *Oesophagostomum* spp. were found in very low numbers in the cultures during one week in December 2003.

As judged by the nematodes recovered following the slaughter of the goats, *Trichostrongylus* spp. were most abundant, followed by *Haemonchus* spp. and other species (Fig. 3). Of the *Trichostrongylus* spp., *T. falculatus* was the most common and only limited numbers of *T. axei* and *T. colubriformis* were recorded. The other species identified included small numbers of

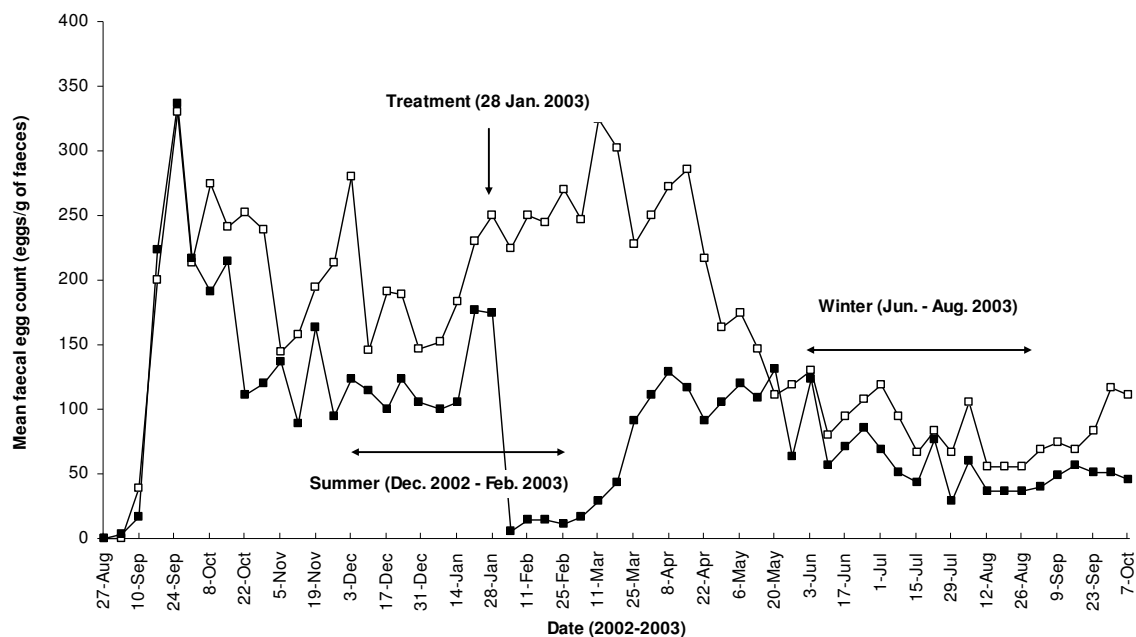


Fig. 2: Faecal egg counts (eggs per g, egg) for the 36 Boer goats treated tactically and symptomatically (■) with ivermectin compared to the 36 goats given symptomatic treatment only (□)

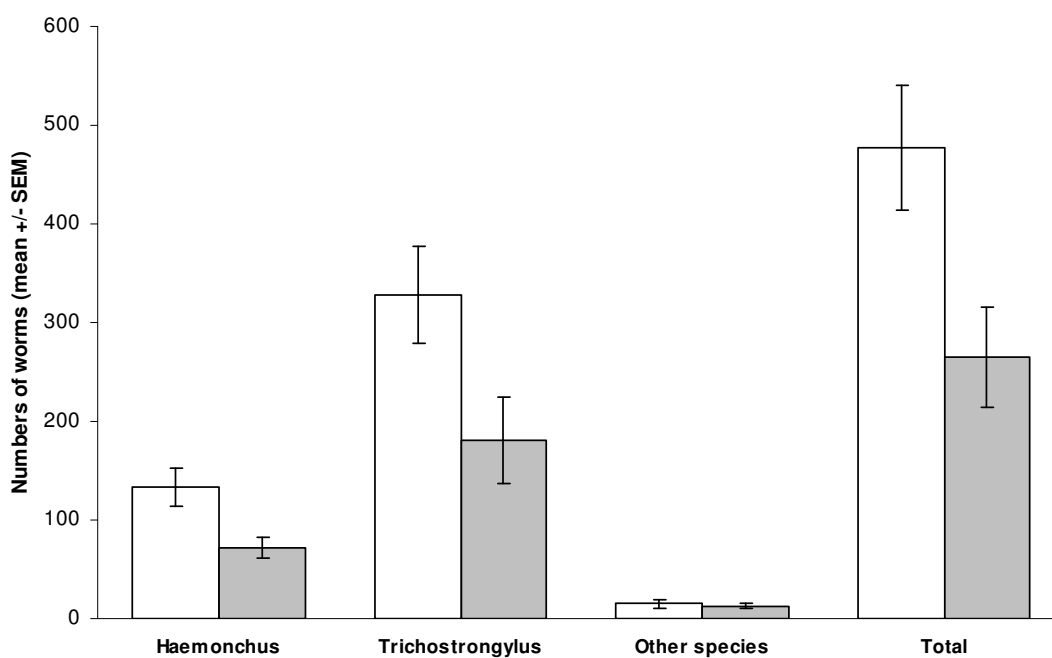


Fig. 3: Mean worm counts (\pm standard error of the mean) for the 36 Boer goats treated tactically and symptomatically with the anthelmintic ivermectin (shaded columns) compared to the 36 goats given symptomatic treatment only (non-shaded columns)

Teladorsagia spp., *Strongyloides papillosus*, *Impalaia tuberculata*, *Trichuris* spp. and *Oesophagostomum* spp. (on average, 14 nematodes of these other species). There were significant differences between the tactically and non-tactically treated goats for *Haemonchus* spp. counts, *Trichostrongylus* spp. counts and total counts ($P < 0.05$), but there were no significant differences between feed groups ($P > 0.05$).

Production parameters

With the exception of 11 March 2003, there were no significant differences in mean liveweight between the tactically and non-tactically treated groups. Although the worm burdens between the tactically and non-tactically treated goats were significantly different ($P < 0.05$), there were never any statistically significant differences in the liveweight gain ($P > 0.05$), in the body condition scores ($P > 0.05$) or in the cold dressed-out carcass weights ($P > 0.05$) between the tactically and non-tactically treated groups (data not shown). Thus the gastrointestinal parasites had no significant effect on the production parameters of the goats.

The dry-season-supplemented goats showed the greatest liveweight gain overall (Fig. 4). From the end of July 2003 until the end of the experiment, the differences in weight gain by date between the controls and the dry-season-supplemented goats were generally significant ($P < 0.05$). The weight gains by date for the wet-and-dry-season supplemented goats were higher than those of the controls but lower than those of the dry-season supplemented goats during this period but the differences were not significant. The wet-season supplemented goats had lower weight gains than the controls but the differences were also not significant.

Body condition improved during the wet season and was highest in the mid-autumn period, but declined slightly during the dry winter (Fig. 5). When the feed groups were compared, the body condition scores of the dry-season-supplemented and the wet-and-dry-season-supplemented groups were significantly higher than the scores of the controls on several occasions from, respectively, mid-December and mid-February onwards ($P < 0.05$).

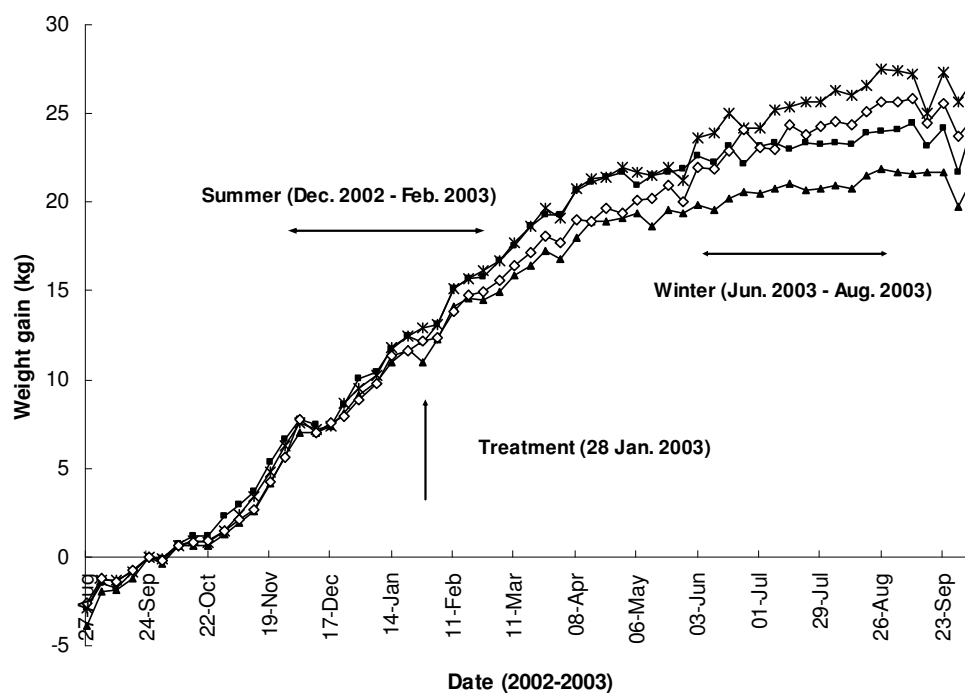


Fig. 4: Weight gains for the four different feed groups of 18 Boer goats each. One group received no urea-molasses block supplementation (Control, ■), one group received urea-molasses block supplementation in the summer (Wet, ▲), one group received urea-molasses block supplementation in the winter (Dry, *) and one group received urea-molasses block supplementation in the summer and winter (Wet-and-Dry, ◇)

Anaemia levels and clinical biochemistry

Throughout the study period, the seasonal mean haematocrits were in the range of 23.8-25.5 % (Table 4) thus remaining within, but at the lower end of the normal haematocrit range for goats of 22-38 % (Feldman *et al.*, 2000). Notably, the mean haematocrit readings were at their lowest when *Haemonchus* spp. were predominant *i.e.* spring/summer 2002/2003 (Table 4 and Fig. 2). Any statistically significant differences between supplemented groups and controls and between tactically and non-tactically treated groups were always less than three percentage points and were considered clinically marginal as at no time did the mean of any of these groups fall below 22 % (data not shown). The mean FAMACHA[®] scores for the groups were lower than 2.4 on all occasions and closely mirrored the trend in haematocrits (data not shown). Individual goats were treated as their FAMACHA[®] scores were '3' or '4', but no scores of '5' were recorded and only on four occasions were goats scored as '4'. There were no significant differences between

experimental groups in the average number of days on which goats received treatment for various conditions (including symptomatic treatment according to the FAMACHA[®] system) (Table 5).

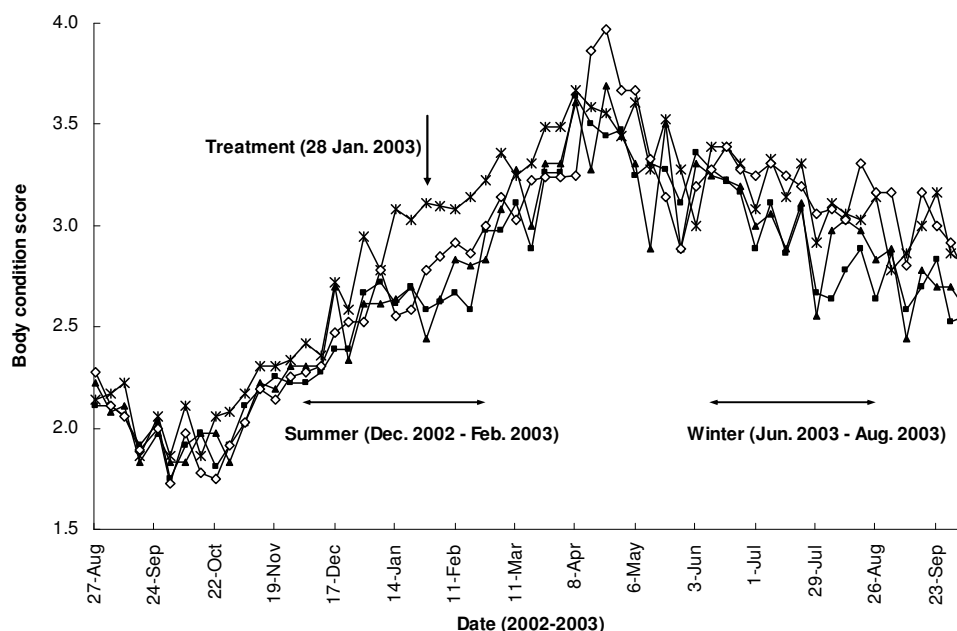


Fig. 5: Body condition scores for the four different feed groups of 18 Boer goats. One group received no urea-molasses block supplementation (Control, ■), one group received urea-molasses block supplementation in the summer (Wet, ▲), one group received urea-molasses block supplementation in the winter (Dry, *) and one group received urea-molasses block supplementation in the summer and winter (Wet-and-Dry, ◇). Data for 4 February, 25 March and 1 April 2003 were not obtained and the values shown are averages between the available values immediately before and after the missing values

The mean serum total protein values calculated for the goats in total remained within the normal reference range of 55.4-71.8 g/l (J. Muller, Golden Vetlab, pers. comm., 2002) and generally at a level of 64.4 g/l (Table 4). The overall mean serum albumin values also remained within the normal reference range of 20.1-29.4 g/l and generally at a level of 25.9 g/l. Any statistically significant differences between supplemented groups and controls and between tactically and non-tactically treated groups were always less than 4 g/l for serum total protein and 3 g/l for serum albumin. The differences were considered clinically marginal as, with only a few exceptions when the means for albumin approached 30 g/l, the means were within the normal reference ranges. From October 2002 to the end of February 2003 the overall mean serum urea

values were *ca.* 5.77 mmol/l, with highest levels in the summer. However, from March 2003 onwards, the mean value declined to *ca.* 3.35 mmol/l, which was below the normal range of 4.62-9.62 mmol/l. Any statistically significant differences in urea levels between supplemented groups and controls and between tactically and non-tactically treated groups were again considered clinically marginal (maximum difference: 1.10 mmol/l), most of these differences occurring during the latter half of the study when the urea levels were low in all the goats.

Table 5: Problems noted in the four feed groups of experimental goats. Each value represents the average number of days over the study period for which goats within each group were treated for a particular problem

Problem	Treatment			
	Control	Dry	Wet	Wet-and-dry
Respiratory tract infections	0.7	0.2	0.7	0.6
Coccidiosis and diarrhoea	0.1	0.9	0.2	0.2
Abscesses	6.6	7.1	5.1	3.0
Joint problems/lameness	1.8	0.2	1.1	3.7
Anaemia (FAMACHA [®] 3 or 4; treated)	1.3	0.6	0.9	1.5
Eye infections	0.1	0.2	0.1	0.7
Other problems (e.g. wounds, ticks)	0.4	0.8	0.0	0.3
Total	10.6	9.6	7.9	9.6

Dry: dry-season supplementation.

Wet: wet-season supplementation.

Wet-and-dry: wet-and-dry-season supplementation.

Economic analysis

Although the difference was not significant at the 5 % level, at the 10 % level the mean cold dressed-out carcass weight of the winter dry-season-supplemented group (26.4 kg) was statistically significantly greater than that of the control group (24.7 kg). The wet-season-supplemented group had the lowest mean dressed-out carcass weight (23.3 kg) while the mean carcass weight of the wet-and-dry-season-supplemented group was similar to that of the control group (24.6 kg). When the cost-benefit analysis was carried out, and the cost of tactical drug treatment and urea-molasses block supplementation considered, only winter dry-season supplementation without tactical treatment (Group 3) proved economically viable.

DISCUSSION

The occurrence of larvae of *Haemonchus* during October to March and larvae of *Teladorsagia* / *Trichostrongylus* during June to October agrees with the results of previously published studies on the occurrence of these parasites in sheep and goats in the summer rainfall area of South Africa (Horak and Louw, 1977; Horak, 1978; Boomker *et al.*, 1994). The origin of the other species was probably from the cattle which had previously grazed the paddock and the impalas which continued to graze the paddock throughout the experiment (Horak, 1981; Soulsby, 1968).

The degree of infection established in the goats in the present study was low as noted both by the faecal egg counts and by nematode recovery (Hansen and Perry, 1994). While the unusually dry weather during November 2002 was most probably detrimental to the survival of *Haemonchus* larvae on the pasture, the grazing area was probably too large relative to the number of goats grazed on it to allow adequate infection of the pasture for the experiment. The infection of the goats could probably have been exacerbated by establishing a heavy infection on the pasture by grazing small ruminants on it for 1 to 2 years before the experiment, by using a trickle infection to infect the goats (Barger *et al.*, 1985), and by utilizing a pasture with fewer or no browse species in order to encourage the goats to graze.

The general finding in this study was that since the parasite burdens were low, the tactical treatment of the gastrointestinal nematode infections had no significant effect on the production parameters of the goats but that the nutritional factors probably had a relatively bigger impact.

The paddocks where the goats grazed can best be described within Acocks (1988) classification as Other Turf Thornveld, specifically Norite Black Turfveld. These paddocks had a range of bush species available, which the goats were assumed to have browsed throughout the year. The availability of these browse species in the herbage may have accounted for the fact that the acid detergent fibre and neutral detergent content of the herbage remained relatively consistent throughout the year. As is to be expected, the dry matter and crude protein of the herbage varied with the seasons, being lowest and highest, respectively during the wet summer period (Table 4). During the winter period, the dry matter was highest and the crude protein lowest. The serum urea

values gave an immediate indication of the availability of crude protein in the pasture as it was highest during the summer period and lowest during the winter and subsequent spring. The serum albumin and body condition scores also reflected the availability of crude protein in the pasture, but there was a lag period before a change became evident. For example, highest values of crude protein recorded in the summer period were only reflected in highest values for albumin and body condition scores in the autumn. Although the mean haematocrits were at the lower end of the haematocrit range for goats as given by Feldman *et al.* (2000), the values are similar to normal values reported for goats 1-2 years old from India (22.6 %) and Nigeria (26.9 ± 3.8 %), but lower than values reported for adult wethers from the UK (34.8 ± 3.8 %) and adult goats from the United States (34.0 ± 4.9 %) (Smith and Sherman, 1994).

The crude protein content of the herbage during summer was probably sufficient to fulfil the goats' growth needs, as shown by increasing body condition scores during this period. As such, any additional urea intake will have been inefficiently utilized and lost in the urine. In the winter, however, the crude protein of the herbage had declined and there was an apparent shortage of dietary crude protein as evidenced by a decrease in body condition and in low serum urea levels. As a result, supplementation of the goats during this period was beneficial. However, intake of the urea-molasses blocks was low. The reasons for this are unclear, but an improved intake of the blocks may have resulted in a better effect on the growth of the goats and the resultant dressed-out carcass masses.

An alternative to urea-molasses block supplementation for parasitized ruminants is the use of bypass protein which is found in the by-products of vegetable oil extraction, i.e. oil cake meals. Magaya *et al.* (2000) showed a beneficial effect of cottonseed meal supplement with or without anthelmintic treatment on growth performance of parasitized weaner steers in Zimbabwe. Supplementation of ruminants with oil cake meal tends to be expensive and researchers have thus examined the use of locally available sources of protein as dry-season supplements, including leguminous browse species and their pods (Aganga and Wani, 1998; Sikosana *et al.*, 2004). Harvesting of the leaves and pods of such leguminous plants may be feasible on a sustainable basis in areas of the summer rainfall area of southern Africa where they occur.

The cost-benefit analysis of the present study, nevertheless, indicated that dry-season, winter supplementation of Boer goats with urea-molasses blocks from June to August without tactical anthelmintic treatment, was associated with a 6 % increase in carcass value over the corresponding controls. This equated to US\$ 3.30 per animal which is considered economically viable and worthwhile.

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Chapter 4

BENEFITS OF UREA-MOLASSES BLOCK SUPPLEMENTATION AND SYMPTOMATIC AND TACTICAL ANTHELMINTIC TREATMENTS OF COMMUNALLY GRAZED INDIGENOUS GOATS IN THE BULWER AREA, KWAZULU-NATAL PROVINCE, SOUTH AFRICA

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ABSTRACT

This study was carried out with the cooperation of farmers owning communally grazed indigenous goats in south-western KwaZulu-Natal Province, South Africa, where farmers had identified poor reproductive performance in their herds as one of their major problems. The aim was to quantify the effects of three interventions and the interaction between these interventions on goat productivity and gastrointestinal nematode infection. The interventions were: urea-molasses block supplementation during the dry winter seasons of 2004 and 2005, tactical anthelmintic treatment with ivermectin (400 µg/kg) during the wet summer period (on 3 January 2005) and symptomatic treatment with ivermectin (400 µg/kg) of all goats judged anaemic throughout the entire study period. The FAMACHA[®] system was used as a gauge of anaemia. It was noted that goats considered anaemic tended to remain so throughout the study period. The tactical anthelmintic treatment was effective as it markedly reduced ($P = 0.066$) the summer peak in faecal egg counts and is therefore recommended. By contrast, while the urea-molasses block supplementation appeared to reduce the faecal egg counts immediately following the 2004 supplementation ($P < 0.05$), this did not hold true in 2005. Interestingly, in the tactically treated anaemic goats, the improvement in the number of kids suckled per doe year-on-year tended to be greater than in the non-anaemic goats. It is considered that the routine symptomatic treatment of anaemic goats may have been a key factor. More detailed investigations into the routine symptomatic treatment of anaemic goats are therefore recommended.

Key words: FAMACHA[®], gastrointestinal nematodes, symptomatic and tactical anthelmintic treatment, urea-molasses blocks, Zulu goats.

INTRODUCTION

In the summer rainfall area of South Africa internal helminth parasites are an important cause of disease in communally grazed indigenous goats belonging to resource-poor farmers of KwaZulu-Natal Province, South Africa (Vatta *et al.*, 2002a,b). Dry-season (winter) feed scarcity was identified as an important constraint to improving goat productivity in these animals (Vatta *et al.*, 2002b). Resource-poor communities have also indicated that poor reproductive performance of goats is a major concern (De Villiers and Letty, 2001). Studies with Boer goats on extensive grazing at Onderstepoort Veterinary Institute, Gauteng Province, in the summer rainfall area of South Africa showed that urea-molasses block supplementation during the dry winter period (June to August) resulted in heavier cold dressed-out carcass weights compared with weights of non-supplemented controls (Vatta *et al.*, 2005). The increase in carcass value showed that supplementation was economically justifiable. The aim of the present investigation was to quantify the effects of three interventions and the interaction between these interventions on gastrointestinal nematode infection and goat productivity. The interventions were: urea-molasses block supplementation during the dry winter seasons of 2004 and 2005, tactical anthelmintic treatment during the wet summer period and symptomatic treatment of all goats judged anaemic throughout the entire study period. The FAMACHA[®] system was used to identify anaemic goats as this is simple and practical for use on-farm (Bath *et al.*, 2001).

MATERIALS AND METHODS

Selection of the farms and goats used in the study

The study area, comprising the three goat-keeping communities of Nkwezela, Hlafuna and Njobokazi, near Bulwer, falls within the Moist Highland Sourveld and Moist Tall Grassveld Bioresource Groups (Camp, 1997). The topography comprises rolling hills to mountainous areas and is primarily suited to extensive livestock production (Camp, 1997). The homesteads of the participating farmers were situated at 1 214 to 1 532 m above sea level. With the exception of

January and February 2004, the monthly rainfall for Bulwer was similar to the average monthly rainfall for 1990-2002 (Fig. 1).

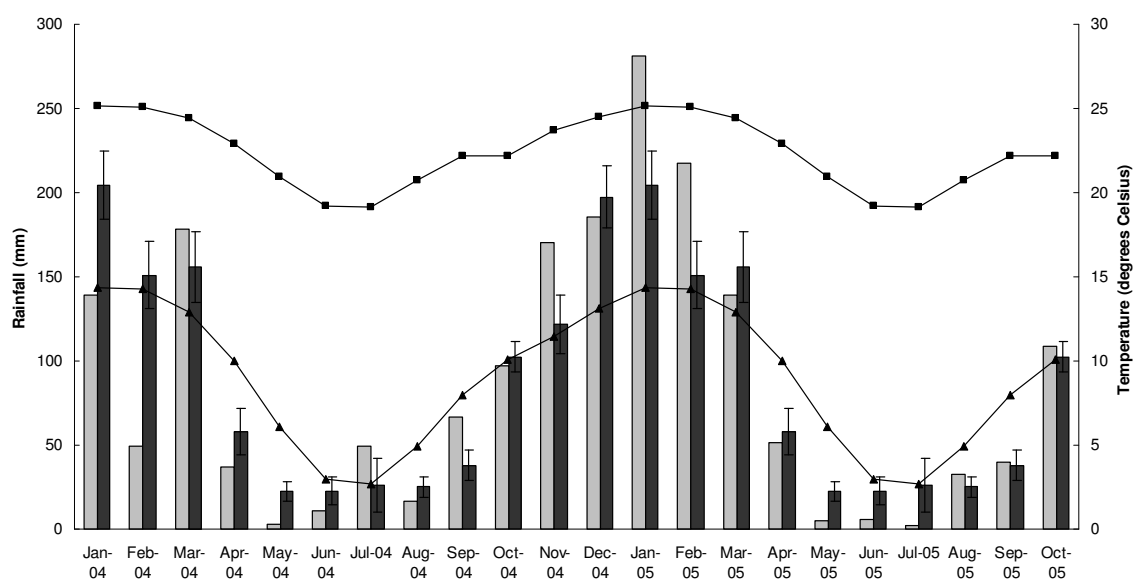


Fig. 1: The monthly rainfall data for Bulwer, South Africa, over the experimental period (light-grey columns), the average monthly rainfall data for Bulwer for 1990-2002 (\pm the standard error of the mean; dark-grey columns) and the average maximum (■) and minimum (▲) monthly temperatures for Emerald Dale, the nearest weather station to Bulwer that recorded temperature data, for 1990-2002

Farmers with at least seven weaned does were identified within the study area and were invited to participate in the experiment. Three farmers' goat herds were included from each of the villages of Nkwezela and Njobokazi and two from Hlafuna. Within each village, the farmers' goats were extensively grazed on communal pastures.

The ages of the experimental goats were determined at the start of the experiment by examination of the lower incisors and scored as 0-, 2-, 4-, 6- or 8-tooth animals (Mitchell, 1982), where the number corresponds to the number of erupted permanent incisors. For statistical analysis, the goats were divided into younger animals [having four or fewer permanent incisor teeth and estimated to be 18-21 months old or younger (Mitchell, 1982)] or older animals (having more than four permanent incisor teeth and being older than 18-21 months in age). The goats were identified by numbered ear-tags, inserted at the start of the study.

Pasture sampling

Herbage samples were collected from six grazing areas of the village herds on 30-31 August 2004, 25-26 October 2004, 2-3 February 2005 and 25-26 May 2005, dates that fell within the four different seasons. The seasons were defined as winter: 1 June to 31 August; spring: 1 September to 30 November; summer: 1 December to 28 February; and autumn: 1 March to 31 May. The six sites were designed to encompass the various common grazing ranges of the goats on the hillsides. During each collection period, herbage samples were collected by cutting or plucking the grass and herbs falling within a quadrat of 400 mm x 400 mm thrown at random on ten occasions at each of the six grazing areas. The positions where the quadrat fell were identified on the first visit by means of GPS points. The same points were located on each subsequent visit and the quadrat was then thrown from these points during the subsequent visits. The samples from each grazing area were then pooled by site for analysis, as were the various components such as leaves, stems and grass. Samples of browse leaves from shrubs falling within *ca.* 3 m of the place where the quadrat fell were also collected. The samples were dried, milled and analysed by proximate analysis for dry matter, lipid and ash content (AOAC, 1980), crude protein (AOAC, 2002), acid detergent fibre and neutral detergent fibre (Van Soest and Robertson, 1980).

Monitoring and sampling

During the four-weekly visits to the homesteads, from February 2004 to October 2005, the weaned and adult does were weighed with a spring balance able to weigh to 200 kg in 500 g increments (Salter Model 235, Capital Scales, Pretoria, South Africa) and their body condition scored on a scale of 1 (very thin) to 5 (obese) (Russell, 1984; Williams, 1990). At the same time, blood was collected from the jugular vein into evacuated ethylene diamine tetra-acetic acid (EDTA) tubes (Vacutainer Systems, Becton Dickinson, France). The blood was stored in an ice-filled cooler box for transport to a field laboratory and was processed on the same day as collection. Two heparinized microhaematocrit tubes (Brand, Wertheim, Germany) were filled with blood per sample and centrifuged (Hermle Z230 HA, Germany) for eight minutes at 12 000 revolutions per minute. The haematocrits were read for the two microhaematocrit tubes and the mean of the two

readings used in the analyses. Faecal samples were obtained for faecal nematode egg counts (Reinecke, 1983). Faeces were also collected from the experimental animals and from the other goats in the herd for pooled culture for third-stage nematode larvae from May 2004 to October 2005. The faeces were transported in an ice-filled cooler box or stored in a refrigerator until processing in the laboratory. Cultures were made according to Reinecke (1983) and identification of the larvae was done following the key of Van Wyk *et al.* (2004).

Faecal trematode egg counts were carried out according to the method of Malan and Visser (1993) at four-weekly intervals from 3 January 2005 onwards. When two study animals were found to be positive for *Fasciola* spp. eggs on faecal trematode egg count on 3 January 2005, all the goats in the herds were treated with triclabendazole (Fasinex, Novartis South Africa) at a dosage of 10 mg/kg on 31 January or 1 February 2005 and again on 25 or 26 April 2005. The trematode egg counts remained negative for *Fasciola* spp. eggs from 28 February 2005 onwards until the end of the study.

The goats were evaluated according to the FAMACHA[®] system, a method of assessing anaemia which has been tested for use where *Haemonchus contortus* infection is the cause of anaemia (Malan *et al.*, 2001; Vatta *et al.*, 2001). The colour of the conjunctival mucous membranes is compared with a colour chart depicting five gradations of red from '1' to '5', '1' (red) corresponding to 'healthy' and '5' (white) to 'severely anaemic'. Goats that were scored as 3, 4 or 5 were considered anaemic. The scoring was done by the farmer or the farmer's assistant (*e.g.* a son or daughter or goatherd) under the guidance of an experienced evaluator (M D Chipana, M O Stenson or A F Vatta), or by the experienced evaluator himself.

The farmers were asked whether the does were suckling kids (0, 1 or 2 kids) and this information was recorded. Data for 56 does were included in the final analysis.

Experimental design

The experimental interventions are summarized in Table 1. From the end of May until the end of September 2004 and again from the beginning of June to the end of September 2005, three of the eight herds were supplemented with urea-molasses blocks (Voermol Protein Blocks,

Voermol, South Africa) in the animals' kraals (sleeping pens) located at the homesteads. Because management constraints made it impossible to separate supplemented (BLOCK) and unsupplemented (NO-BLOCK) animals within individual herds, each herd was allocated to either the one or the other of the two treatments. The decision on which herds to supplement was based on the presence of a protective roof for the urea-molasses blocks and the need to ensure a comparison between farmers within villages. Hence one herd within Nkwezela and one each from Hlafuna and Njobokazi were supplemented. Only one block was placed in each kraal of supplemented goats at a time. No dominant behaviour of any goats, which would have prevented or limited block consumption by any of the others was observed or reported.

Table 1: Experimental interventions carried out in six groups of communally grazed indigenous goats (Bulwer, South Africa) - supplemented (BLOCK) or not supplemented (NO-BLOCK) with urea-molasses blocks and tactically treated (TT) with ivermectin when scored as anaemic (F[®]/TACT), when scored as non-anaemic (NON-F[®]/TACT) or not tactically treated (NON-F[®]/NON-TACT). Goats were symptomatically treated with ivermectin if scored as anaemic on examination of the conjunctival mucous membrane (according to the FAMACHA[®] system)

Group (<i>n</i>)	2004											2005											
	F	M	A	M	J	J	A	S	O	N	D	J	F	M	A	M	J	J	A	S	O		
F [®] /TACT/BLOCK (10)						B	L	O	C	K	S		TT					B	L	O	C	K	S
F [®] /TACT/NO- BLOCK (17)													TT										
NON- F [®] /TACT/BLOCK (6)						B	L	O	C	K	S		TT					B	L	O	C	K	S
NON-F [®] /TACT/NO- BLOCK (7)													TT										
NON-F [®] /NON- TACT/BLOCK (6)						B	L	O	C	K	S							B	L	O	C	K	S
NON-F [®] /NON- TACT/NO-BLOCK (10)																							

Irrespective of experimental grouping, every goat clinically evaluated throughout the experiment according to the FAMACHA[®] system as being anaemic, was treated with ivermectin

(Ivomec Liquid, Merial South Africa) at a dosage of 400 µg/kg. Within each herd, the does were randomly allocated to two groups balanced for live weight, using the live weights for 6 December 2004. One group was given a tactical treatment with ivermectin irrespective of mucous membrane colour on 3 January 2005; the second group was left untreated, except where animals received symptomatic treatment for anaemia. Tactical anthelmintic treatment is defined as deworming when large worm burdens are expected (Van Schalkwyk *et al.*, 1995). Thus there were four groups of goats: (a) goats that had FAMACHA[®] scores of 1 or 2 that were not treated (non-anaemic-scored and not tactically treated group, NON-F[®]/NON-TACT group); (b) goats that had FAMACHA[®] scores of 1 or 2 that were tactically treated (non-anaemic-scored and tactically treated group, NON-F[®]/TACT group); (c) goats classified according to FAMACHA[®] score as anaemic on 3 January 2005, that had been selected according to live weight on 6 December 2004 for tactical treatment; and (d) goats FAMACHA[®]-scored as anaemic that had not been selected for tactical treatment, but which were treated because they were considered anaemic. The data for groups (c) and (d) were combined for the analyses (anaemic-scored and tactically treated group, F[®]/TACT group).

Statistical analysis

The data were analysed statistically by means of a 2 x 3 factorial analysis of variance (ANOVA) for unbalanced data using the GenStat statistical software (GenStat[®] for Windows[®] 7th edition, VSN International Ltd). Both the main effects of urea-molasses block supplementation (two levels) and tactical anthelmintic treatment (three levels) were examined as well as the interaction of supplementation by tactical anthelmintic treatment. The data were further analysed for effects of age and supplementation, the age by supplementation interaction, age and tactical anthelmintic treatment, and the age by tactical anthelmintic treatment interaction. Treatment means were separated using Fisher's protected *t*-test least significant difference at the 5 % level. The data for the faecal egg counts were log-transformed [$y = \log_{10} (\text{egg count} + 1)$] to stabilize treatment variances, but the untransformed values are reported in the text and figures.

RESULTS

The dry matter content of the herbage was highest during the late dry season, winter sampling time (August 2004) and lowest during the late wet season, summer sampling time (February 2005) (Table 2). The crude protein content of the herbage was lowest during the early dry season (May 2005) and highest during the spring sampling time (October 2004).

Table 2: Average composition of herbage sampled on 30-31 August 2004, 25-26 October 2004, 2-3 February 2005 and 25-26 May 2005 at six sites encompassing the various common grazing ranges of the study goats, in Bulwer, South Africa

	Dry matter (g/kg)	Moisture (g/kg)	Crude protein (g/kg DM)	ADF (g/kg DM)	NDF (g/kg DM)	Lipid (g/kg DM)	Ash (g/kg DM)
Mean	411.3	588.7	75.6	453.2	773.5	21.6	92.5
SD	126.1	126.1	26.7	49.4	57.9	7.8	24.2
SE	22.3	22.3	4.7	8.7	10.2	1.4	4.3
Minimum	266.4	235.8	37.2	371.3	666.2	12.4	52.0
Maximum	764.2	733.6	124.4	574.6	873.0	48.4	174.7
<i>n</i>	24	24	24	24	24	24	24

Key: SD: standard deviation; SE: standard error of the mean; DM: dry matter; ADF: acid detergent fibre; NDF: neutral detergent fibre.

The consumption of urea-molasses blocks by BLOCK goats during the dry, winter season was estimated to be 42 g per goat per day for both the 2004 and 2005 supplementation periods. The amount of block consumed per goat was estimated by dividing the total amount of block consumed by the total number of goats in the herd, including animals not included in the study.

Examination of third-stage nematode larvae derived from faecal cultures showed a predominance of *Haemonchus* larvae throughout the study period, but *Teladorsagia/Trichostrongylus* larvae occurred in higher percentages than the other larvae during the months of July and August 2004 and at the end of January and in May and July 2005 (data not shown). Larvae of *Oesophagostomum*, *Strongyloides* and *Gaigeria/Bunostomum* occurred in very low numbers (on average, making up less than 5 % of the larvae recovered, except for August 2005

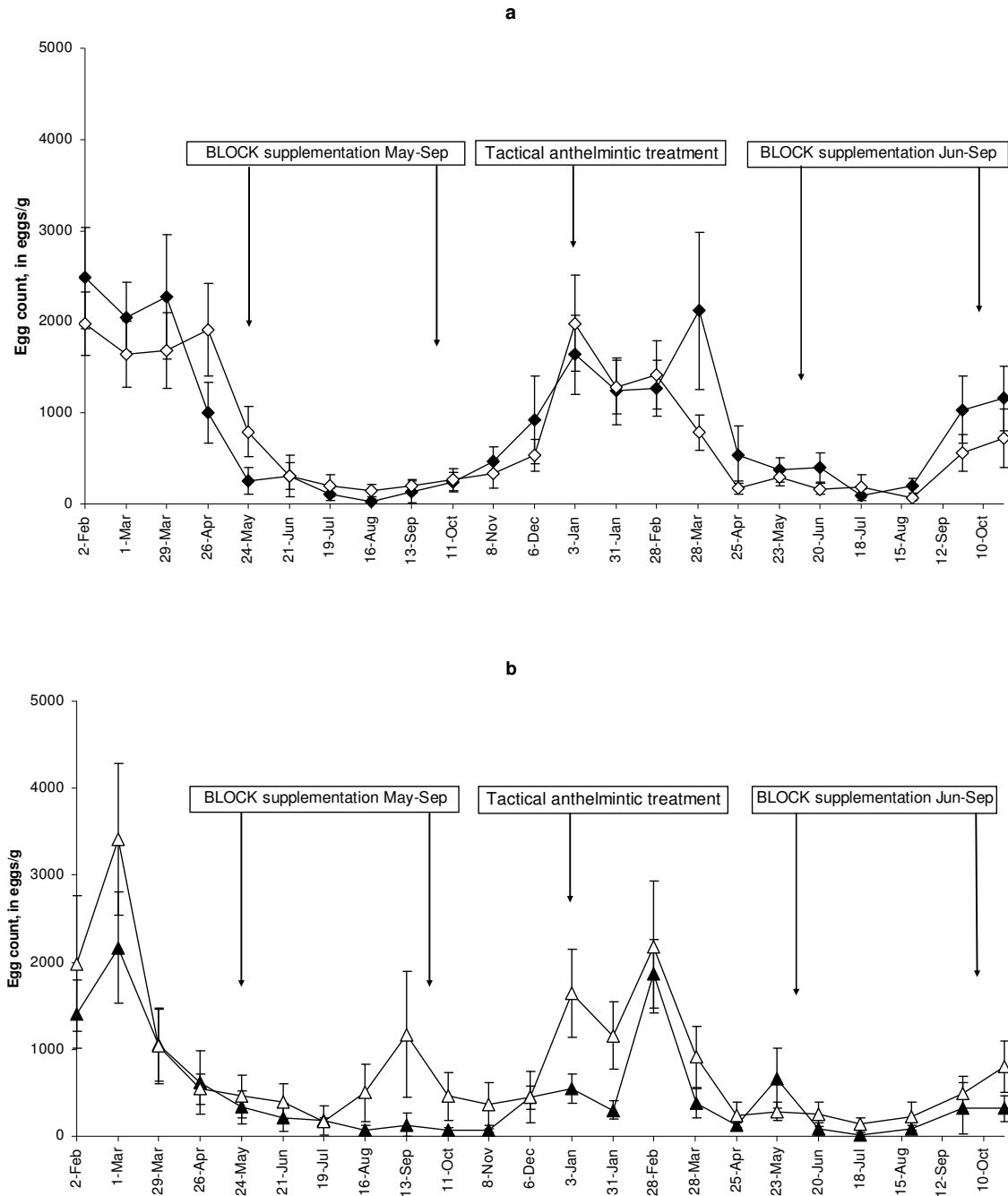


Fig. 2: **Mean faecal nematode egg counts** (in eggs per gram of faeces \pm the standard errors of the means) **for six groups of communally grazed indigenous goats in Bulwer, South Africa, over the experimental period** (February 2004 to October 2005). **a: The faecal egg counts for the F[®]/TACT/BLOCK group** (\blacklozenge , anaemic-scored group, supplemented with urea-molasses blocks and tactically treated with ivermectin) **compared with those for the F[®]/TACT/NO-BLOCK group** (\lozenge , anaemic-scored group, tactically treated with ivermectin but not supplemented with urea-molasses blocks). **b: The faecal egg counts for the NON-F[®]/TACT/BLOCK group** (\blacktriangle , non-anaemic-scored group, supplemented with blocks and tactically treated with ivermectin) **compared with those for the NON-F[®]/TACT/NO-BLOCK group** (\triangle , non-anaemic-scored group, tactically treated with ivermectin but not supplemented with blocks)

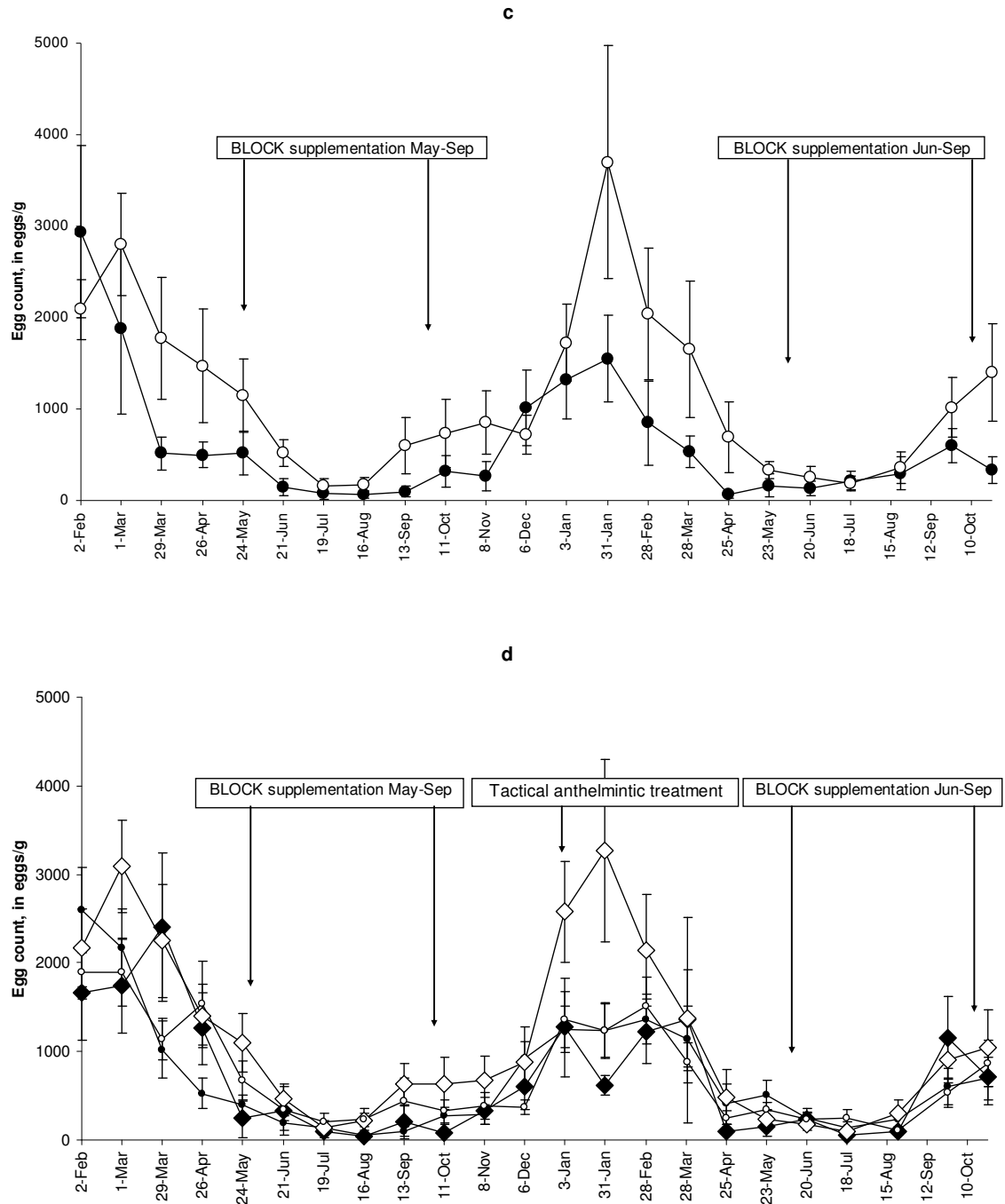


Fig. 2 (continued): **Mean faecal nematode egg counts** (in eggs per gram of faeces \pm the standard errors of the means) for six groups of communally grazed indigenous goats in Bulwer, South Africa, over the experimental period (February 2004 to October 2005). c. The faecal egg counts for the NON-F®/NON-TACT/BLOCK group (●, non-anaemic-scored group, supplemented with blocks but not tactically drenched with anthelmintic) compared with those for the NON-F®/NON-TACT/NO-BLOCK group (○, non-anaemic-scored group, not supplemented with blocks and not tactically treated with anthelmintic). d. The faecal egg counts for the younger goats which were either supplemented (BLOCK, ♦) or not supplemented (◇) with urea-molasses blocks compared with those for the older goats which were either supplemented (BLOCK, ●) or not supplemented (○) with urea-molasses blocks

when *Oesophagostomum* larvae averaged 18%).

Tactical anthelmintic treatment had a transitory effect on the faecal egg counts ($P = 0.066$ for 31 January 2005). These decreased in TACT goats following treatment, but returned to levels similar to those of the NON-F[®]/NON-TACT goats within eight weeks following the treatment (Figs 2a-c; $P = 0.760$ for 28 February 2005). Importantly, the tactical treatment prevented the summer, wet season peak in egg counts which was seen during February in the NON-F[®]/NON-TACT goats. There was no apparent long-term effect on egg counts following the tactical treatment.

The urea-molasses supplementation appeared to have an effect on egg counts in August and September 2004 and the end of January 2005 when the BLOCK animals had significantly lower egg counts ($P < 0.05$) than the NO-BLOCK animals. Otherwise, the differences in egg counts between the BLOCK and NO-BLOCK animals were not statistically significant ($P > 0.05$). There were no significant differences for the interaction of tactical treatment and urea-molasses block supplementation on egg counts ($P > 0.05$).

Although never significantly so, the faecal egg counts for the younger animals (with four or fewer permanent incisor teeth) were generally higher than those of the older animals and this difference was greater during the warmer, wetter months of January to March. The age of the animals did not affect the effectiveness of the tactical treatment. The interaction of age and supplementation was significant only on 24 May 2004 and 3 January 2005 ($P < 0.05$; Fig. 2d). The NO-BLOCK younger goats had the highest egg counts at these times, which were significantly higher than the egg counts of the BLOCK younger goats ($P = 0.004$) in May 2004 and tended towards being significantly higher than the egg counts of this group on 3 January 2005 ($P = 0.083$).

The average haematocrit for the goats was 26.4% during the study. The haematocrits were lower in September 2004 (24.7%) and the months of January to March 2005, with a lowest value of 24.0% at the end of January 2005. An average haematocrit above 28.0% was measured in May and June 2005. Differences in haematocrit between BLOCK and NO-BLOCK groups were generally not of statistical significance. Following the tactical treatment, the mean haematocrit for the F[®]/TACT animals increased by 1.0 percentage point to 24.4% (Fig. 3). The means for the NON-F[®]

animals decreased by 0.8 and 2.6 percentage points to 24.4% and 22.8% for the NON-F[®]/TACT and NON-F[®]/NON-TACT goats, respectively. Differences between these groups were not significant statistically ($P = 0.158$) and there were no long-term effects of the tactical treatment on haematocrit. The younger goats showed significantly lower haematocrits than the older goats in October and November 2004 and in March and April 2005, but the values were within the normal range of 22-36 % for goats (Cebra and Cebra, 2002).

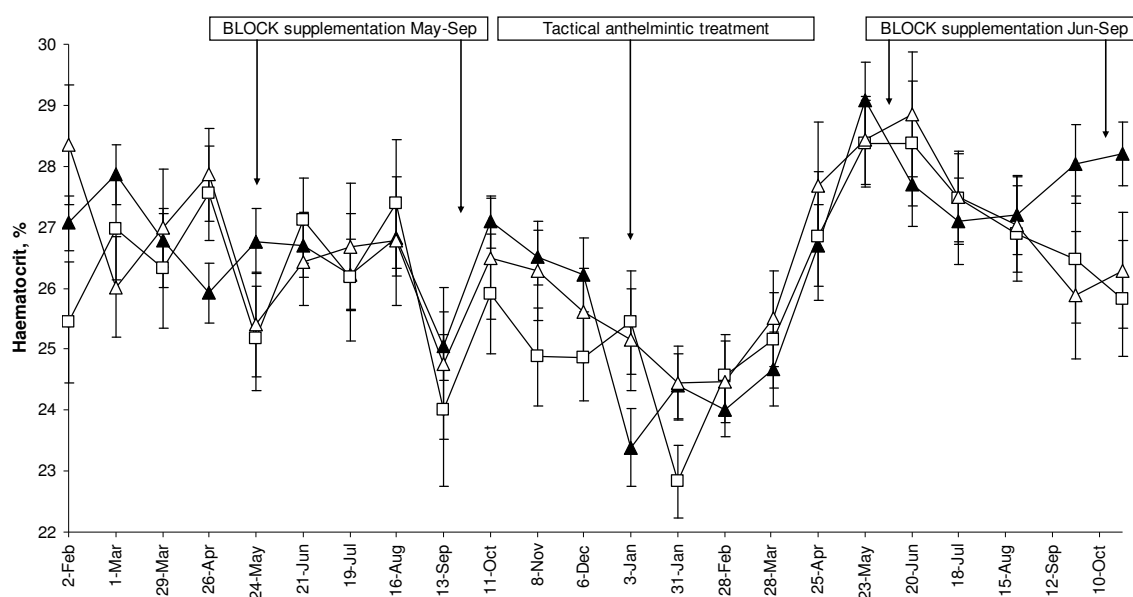


Fig. 3: The mean haematocrits (\pm the standard errors of the means) for the anaemic-scored (F[®]/TACT, \blacktriangle) and non-anaemic-scored (NON-F[®]/TACT, \triangle) groups of goats that were tactically treated with ivermectin and for the non-anaemic-scored group that was not tactically treated (NON-F[®]/NON-TACT, \square), Bulwer, South Africa

One goat that had a FAMACHA[®] score of 2 in September 2004 had a haematocrit of 17 % and was dewormed. All other goats that had haematocrits less than 19 % had been treated as their FAMACHA[®] scores were 3. No goats were scored as 5 during the entire study. Although the FAMACHA[®] scores were not analysed by means of the ANOVA, there were no apparent differences in FAMACHA[®] scores between BLOCK and NO-BLOCK animals; however, the FAMACHA[®] scores for the F[®]/TACT group were marginally higher than the scores for the NON-F[®] groups (Fig. 4). The scores for the younger goats were marginally lower than those of the older goats (data not shown). The paler FAMACHA[®] scores in the F[®]/TACT goats were not mirrored by

higher egg counts and lower haematocrits in this group when compared with the egg counts and haematocrits for the NON-F[®]/TACT and NON-F[®]/NON-TACT groups.

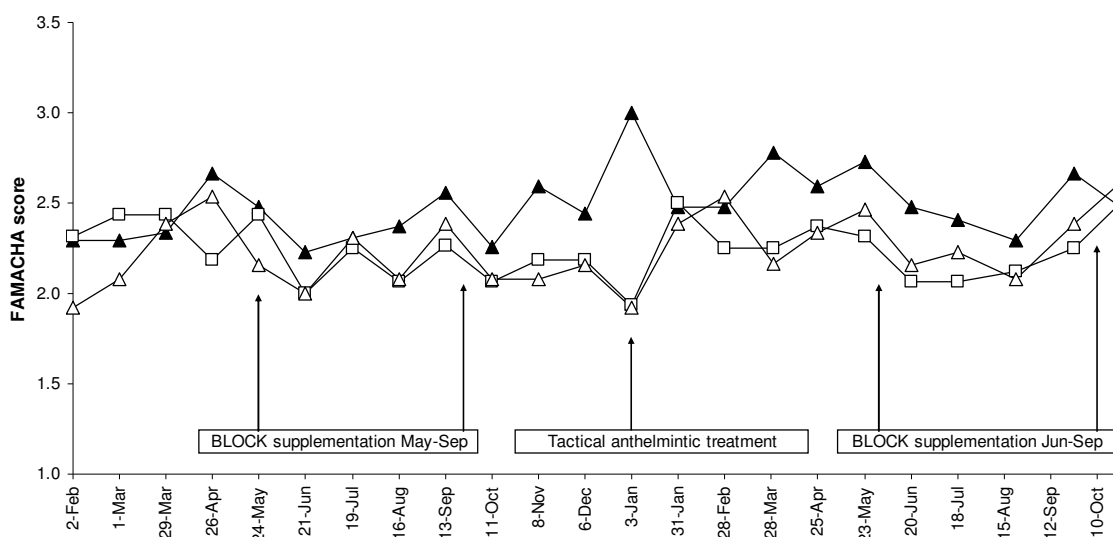


Fig. 4: The mean FAMACHA[®] scores for the anaemic-scored (F[®]/TACT, ▲) and non-anaemic-scored (NON-F[®]/TACT, △) groups of goats that were tactically treated with ivermectin and for the non-anaemic-scored group that was not tactically treated (NON-F[®]/NON-TACT, □), Bulwer, South Africa

The average body condition scores of the goats varied between 2.0 and 2.5, except for September 2005 when the scores dropped to 1.8. With the exception of a few dates, there were no statistically significant differences between the body condition scores of the various groups (data not shown).

The live weights of the BLOCK animals were almost always lower than those of the NO-BLOCK animals, but this difference was generally not statistically significant. The live weights for the F[®]/TACT and NON-F[®] groups were generally similar throughout the study. The younger animals generally had statistically significantly lower live weights than the older animals. The live weights of all the animals decreased by approximately 2.1 kg in September 2004 and August 2005, but the goats recovered this loss in weight during the subsequent one to two months. At the end of the study the animals had gained an average of 4.0 kg in live weight. Weight gain in BLOCK goats at the end of the study was lower than in NO-BLOCK goats (a difference of 1.8 kg), but was not statistically significant ($P = 0.105$). The younger animals showed significantly greater weight gains

than the older animals (6.3 kg *versus* 2.7 kg; $P = 0.003$). Both younger and older BLOCK animals showed lower weight gains than their NO-BLOCK counterparts, but the interaction was not significant. The weight gain in the NON-F[®]/NON-TACT animals (5.9 kg) was higher, but not significantly so, than the weight gain in the F[®]/TACT (3.2 kg) and NON-F[®]/TACT (2.9 kg) groups (Fig. 5). The interaction between age and tactical treatment on weight gain at the end of the study was not significant.

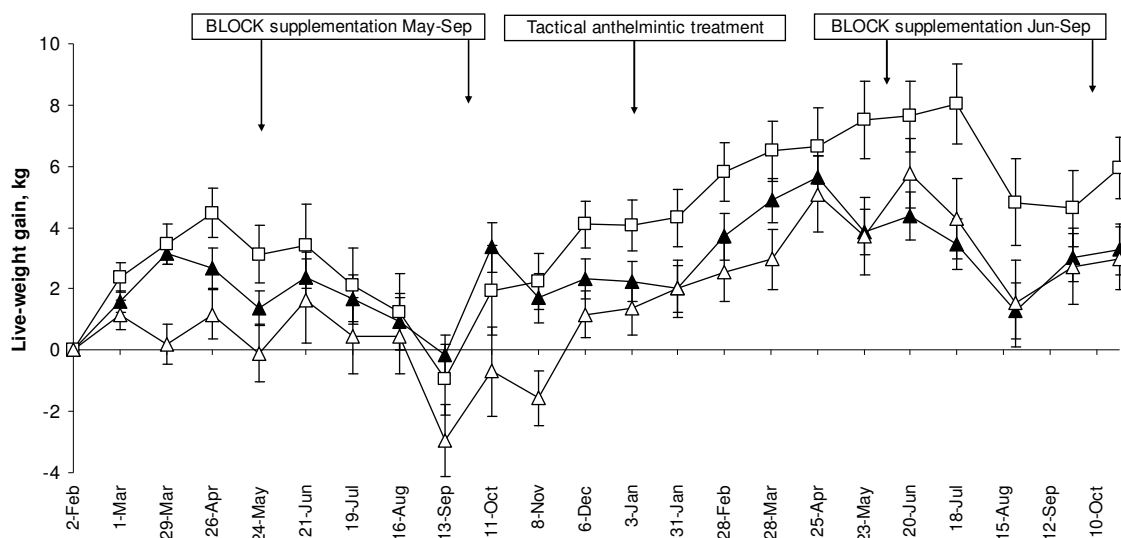


Fig. 5: The mean live-weight gains (\pm the standard errors of the means) for the anaemic-scored, tactically treated group (F[®]/TACT, ▲), the non-anaemic-scored, tactically treated group (NON-F[®]/TACT, △) and the non-anaemic-scored, not tactically treated group (NON-F[®]/NON-TACT, □) of the communally grazed indigenous goats, Bulwer, South Africa

There appeared to be a yearly cycle in the kids suckled per doe, with the number of kids suckled per doe decreasing in March and April (Fig. 6). It was therefore considered appropriate to compare the differences in the numbers of kids suckled per doe year-on-year for 2004 and 2005. The differences were determined by subtracting the number of kids suckled by a doe for a particular sample date in 2004 from the number of kids suckled by that doe on the corresponding date in the subsequent year. This was determined for the months of February to October and the average difference year-on-year per doe per group is presented in Figs 7a-c.

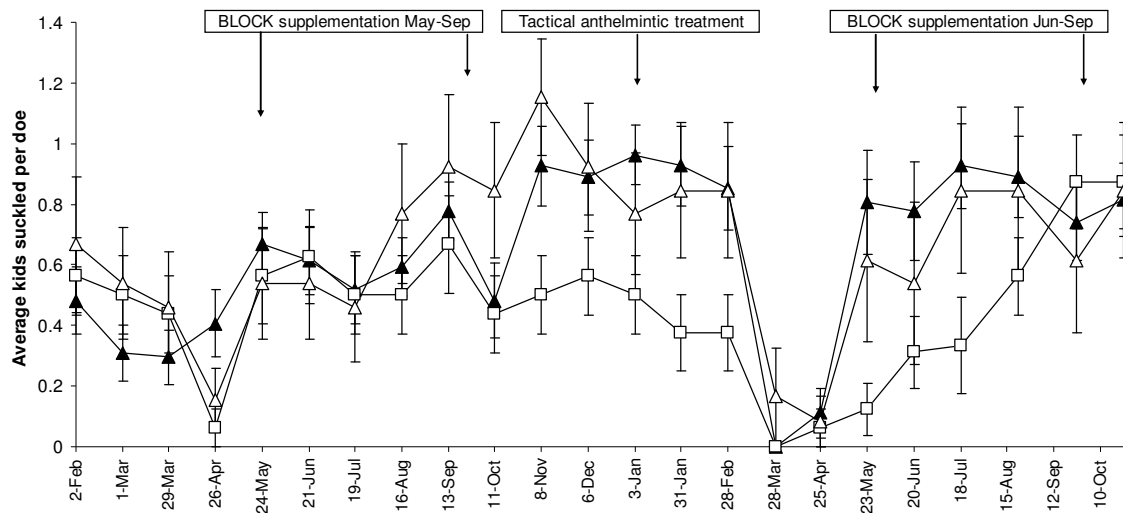


Fig. 6: The kids suckled per doe (\pm the standard errors of the means) by visit date for the anaemic-scored, tactically treated group (F[®]/TACT, ▲), the non-anaemic-scored, tactically treated group (NON-F[®]/TACT, △) and the non-anaemic-scored, not tactically treated group (NON-F[®]/NON-TACT, □) of the communally grazed indigenous goats, Bulwer, South Africa

The overall average difference in kids suckled per doe year-on-year was 0.058. The difference in the kids suckled per doe in the younger goats was 0.178, while the difference for the older goats was -0.009. Within the treatment groups, the same trend was evident, with younger goats showing greater increases in kids suckled per doe than the older goats. Overall, urea-molasses block supplementation did not appear to improve the number of kids suckled per doe. In the F[®]/TACT and NON-F[®]/TACT goats there was a trend towards an increase in the number of kids suckled (0.170 and 0.088 kids suckled per doe year-on-year, respectively). In the NON-F[®]/NON-TACT goats, there was no improvement in the number of kids suckled over the course of the study (-0.131 kids suckled per doe year-on-year). None of the differences in kids suckled per doe year-on-year between age groups and between treatment groups were statistically significant ($P > 0.05$).

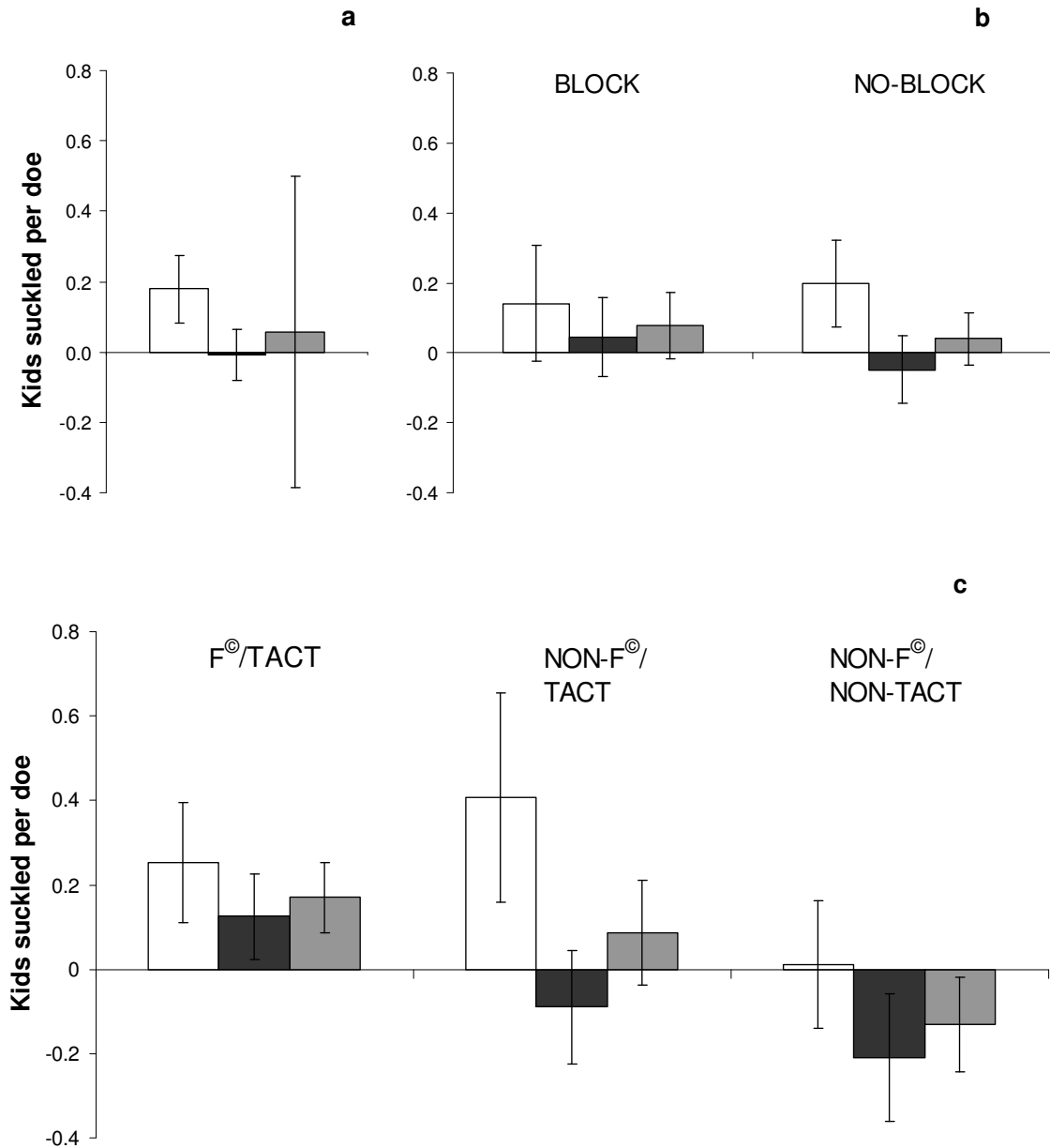


Fig. 7: The average difference (\pm the standard errors of the means) in the number of kids suckled per doe year-on-year (2004/2005) for the communally grazed indigenous goats. a. The difference in the number of kids suckled per doe (light-grey columns) overall as well as the difference between the number of kids suckled per doe for the younger (white columns) *versus* the older goats (dark-grey columns). b. The difference between the number of kids suckled per doe for urea-molasses supplemented (BLOCK) versus non-supplemented (NO-BLOCK) goats. c. The difference between the number of kids suckled per doe for the anaemic-scored, tactically treated group (F[⊙]/TACT), the non-anaemic-scored, tactically treated group (NON-F[⊙]/TACT) and the non-anaemic-scored, not tactically treated group (NON-F[⊙]/NON-TACT)

DISCUSSION

On-station supplementation of extensively grazed Boer goats with urea-molasses blocks, during the dry winter season in the summer rainfall region at Onderstepoort, without tactical anthelmintic treatment in the wet summer season, resulted in greater carcass values over controls (Vatta *et al.*, 2005) even though intake of block was also low in this experiment (77-78 g per goat per day, unpublished data). However, mean faecal nematode egg counts for the goats were low (less than 400 eggs per gram of faeces, epg) throughout the period of this study. It was decided to test the tactical anthelmintic treatment on-farm as the egg counts were expected to be higher. This was the case in the present study, with a period of higher egg counts observed during January to March and mean faecal egg counts calculated for all animals peaking at 2 227 epg and 1 605 epg in March 2004 and January 2005, respectively. The predominant nematodes in the goats were *Haemonchus* spp. and this would account for the decrease in the haematocrits observed during the months of January to March 2005.

For the purposes of this investigation, the pasture infectivity levels were assumed to be similar between the three communities and between communal grazing areas within those communities themselves. The pastures in the communities have similar geographical features such as hills, streams and open pastures; the pastures were subjected to similar weather conditions; they were similarly utilized for grazing, being criss-crossed by sheep, goats, cattle and horses of the community; the ages, breeds and numbers of animals on the pastures appeared to be similar and anthelmintics were used sparingly in the animals, as far as could be determined.

In the absence of data on the age of maturity in the indigenous Zulu goats raised on communal pastures, the division of the goats into younger and older animal groups was somewhat arbitrary. It was reasoned that the animals may take up to two years to mature which would correspond to animals with four permanent incisor teeth (Mitchell, 1982). The only statistically significant differences between the younger goats and the older goats in terms of the parameters measured were seen in live weight and live-weight gain. The younger goats generally had lower live weights than the older goats and they showed a greater weight gain than the older goats, as they were still growing. Though not statistically significant, the egg counts of the younger animals

were higher during January and February 2005 than the counts of the older animals. The difference in number of kids suckled per doe year-on-year was greater in the younger animals than in the does with more than four permanent incisor teeth, though this difference was not statistically significant. This may have happened because a proportion of the younger animals may not have reached reproductive maturity to produce a kid during the first year of the study, creating the greater difference seen year-on-year.

During the dry season, the nutritional status of the natural grazing decreased. This was reflected in a higher dry matter content and lower crude protein content of the herbage, and by a decrease in the live weight, body condition score and haematocrits of the goats during the dry season. Supplementation with urea-molasses blocks during the dry winter season may then have been expected to have a positive effect on production parameters such as live weight, live-weight gain, body condition and the numbers of kids suckled per doe, as well as on the health of the animals as measured by faecal nematode egg count, haematocrit and FAMACHA[®] score. In the current study, the effects of the supplementation were equivocal. BLOCK and NO-BLOCK animals generally did not show statistically significant differences in body condition scores, live weights, live-weight gain, differences in kids suckled per doe year-on-year and haematocrits. FAMACHA[®] scores between the two groups did not differ.

Supplementation did appear to have an effect on reducing the faecal egg counts in the period immediately following and during the wet period following the first year's supplementation ($P < 0.05$), especially in the younger animals. Datta *et al.* (1999) have described the long-term effects on resistance to nematode infection and live-weight gain of the short-term provision of protein-enriched diets to weaner sheep.

The consumption of the urea-molasses blocks was low. The manufacturer recommends 100-140 g per sheep per day (Voermol Pasture Supplements Product Handbook, 2nd edition, Voermol, Maidstone, South Africa). Greater effects of the supplementation may have been seen had the consumption of the blocks been higher. The reason for the relatively low consumption of the blocks is not known.

The separation of the animals into F[®]/TACT and NON-F[®] groups based on their FAMACHA[®] scores in January 2005 was justified as the F[®]/TACT goats had consistently higher FAMACHA[®] scores than the NON-F[®] animals (Fig. 4). The FAMACHA[®] system in goats using a cut-off for treatment of 3 has been shown to have a relatively high sensitivity, but low specificity (Vatta *et al.*, 2001; Kaplan *et al.*, 2004), which means that there are a relatively large number of goats that are scored as 3, 4 or 5 but which are in fact not anaemic on haematocrit reading (false positives) and are therefore unnecessarily treated. This probably explains why the mean haematocrits for the F[®]/TACT group and NON-F[®] groups were generally within the same range (Fig. 3). This is not a problem as such, since additional anthelmintic treatments to non-anaemic animals are not harmful and may actually be beneficial if those animals are harbouring subclinical nematode infections.

Tactical anthelmintic treatment was apparently effective in reducing the peak in faecal egg counts in the TACT goats at the end of January 2005 ($P = 0.066$) when compared with the NON-F[®]/NON-TACT animals. Tactical treatment generally had no statistically significant effect on body condition score, live weight, live-weight gain, difference in kids suckled per doe year-on-year and haematocrit.

The results of the supplementation of the goats with urea-molasses blocks were equivocal; while the urea-molasses supplementation appeared to reduce the faecal egg counts immediately following the 2004 supplementation ($P < 0.05$), this did not hold true in 2005. This may have been a result of the relatively low consumption of blocks overall.

Tactical anthelmintic treatment of goats should be recommended in late December or early January given the apparent effectiveness of this treatment in reducing the faecal egg counts when administered before the expected peak in egg counts. Also, the treatment would act as a hedge against losses in those years when there may be a higher challenge than that recorded during the present study.

The resource-poor goat farmers of south-western KwaZulu-Natal Province, South Africa, had identified poor reproductive performance in their herds as one of their major problems. Any improvements in the number of kids suckled per doe would therefore be of benefit to the farmers.

Though not statistically significant, the number of kids suckled per doe year-on-year was higher in the F[®]/TACT group overall (Fig. 7c) than in the NON-F[®] groups. This indicates that the symptomatic treatments may be beneficial in themselves, *i.e.* irrespective of whether tactical anthelmintic treatments are applied or not. The animals in the F[®]/TACT group were treated more frequently than the goats in the other two groups. Each doe in the F[®]/TACT group received on average 12.6 anthelmintic treatments as opposed to 7.9 in the NON-F[®]/TACT group and 7.4 in the NON-F[®]/NON-TACT group. There is also evidence to suggest that the use of a salvage approach to treatment for gastrointestinal nematodes is acceptable to resource-poor farmers in southern Africa (Kumba, 2004). Therefore, further investigations into the potential specific effects of the symptomatic treatment of anaemic goats may be of significant benefit.

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**PARTICIPATION OF ZULU FARMERS IN A GOAT HEALTH RESEARCH AND
EXTENSION PROJECT IN SOUTH AFRICA**

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ABSTRACT

This study took place in the farming community near Bulwer, south-western KwaZulu-Natal province, South Africa. Previous studies in this area indicated that resource-poor farmers considered diarrhoea, gastro-intestinal helminth infection and poor reproductive performance as the major problems affecting their goats and highlighted the need for information on goat health and management. The aim of this study was the development, with the collaboration of the participating farmers, of a flexible framework for the acquisition of skills and knowledge which could ameliorate the problems affecting goat health and productivity. Promulgation of such knowledge and skills, if successfully accomplished, would nurture 'champions' in the local farming community. These farmer 'champions' would then constitute important role models and a local source of advice and encouragement for other farmers in the area. This paper describes the resultant on-farm goat health research and the development of a *Goatkeepers' animal health care manual*. The approach taken exemplifies how the engagement and participation of farmers in such a process may be enhanced, a departure from that of traditional 'transfer of technology' where farmers tended to be regarded as 'passive recipients of information'. The methodology involved 'a hands-on' approach and encompassed a thorough preparatory phase, on-farm experimentation and regular meetings with farmers geared to their current levels of expertise, a process which is equally applicable to other similar agro-ecological zones. There is also scope for universities, researchers and extensionists to assist with the development of farmers' analytical and record-keeping skills, with the strengthening of farmer associations, and with the training of community animal health workers. A case is made for the organizations involved to continue to cross the institutional divides so that the long-term sustainability and development of resource-poor farming communities is ensured.

Key words: farmer participation, goat research, South Africa.

INTRODUCTION

In conventional approaches to agricultural research, technology development and extension, researchers defined the problems to be addressed, developed solutions to the problems and passed these on to extension personnel to hand over to farmers in a process referred to as 'transfer of technology' (Conroy, 2005; Worth, 2006). Development of the technologies was mostly done at the research station and the conditions on-farm, including the farmers' own management type and priorities, were not adequately considered. As such, the technologies developed were often not appropriate for all farmers, particularly the resource-poor. This inadequate situation led to participatory processes being developed whereby the farmers' contribution received greater recognition and researchers assumed a more supportive role (Conroy, 2005). Extension was seen as an integral part of a human development programme (Worth, 2006). Research on-farm where the farming system is considered received greater preference to on-station experimentation as the involvement of the farmer in on-farm research is much stronger.

Researcher-led to farmer-led approaches can be taken for on-farm research (Collinson, 1987; Norman *et al.*, 1994; Schiere *et al.*, 2000; Snapp *et al.*, 2002), with at one extreme, the farmer in control of the experiment, with support from external specialists. Here the farmer is free to develop technologies that are appropriate for his/her situation. The Farming Systems Research (FSR) approach has been considered within the context of a Sustainable Livelihoods framework (Norman *et al.*, 1994; Pound, 2007). This encompasses the natural, social, human, physical and financial assets along with the legal, institutional and political influences on these. Recently, the Innovations Systems approach has been given consideration (Pound and Essegbey, 2007). This expands the spectrum of stakeholders from researchers, extensionists and farmers to include all those involved with producing, processing and marketing of products.

Any approach in which the farmer takes the lead, demands that the farmer is both conversant with the latest available research results, technologies and approaches, and has the necessary confidence and capability. Currently this is the case in the commercial farming sector of South Africa, where private sector extension services are already employed. However, it is uncommon or even non-existent in the resource-poor farming sector (Ngomane *et al.*, 2002), which

is characterized by dependency on the state, poverty, a lack of entrepreneurial skills (Ngomane *et al.*, 2002) and poor access to basic information on animal diseases and their management (Getchell *et al.*, 2002; Letsoalo *et al.*, 2000; Masika *et al.*, 1997a,b; Wells and Krecek, 2001).

A FSR approach (Collinson, 1987) similar to the on-farm adaptive research approach described by Subair (2002) was applied in the present study. This consisted of diagnostic, planning, on-farm experimentation and assessment phases and finally the development of recommendations, demonstration and extension to farmers.

In April 2000, the extension staff of the KwaZulu-Natal Department of Agriculture and Environmental Affairs identified an area that would benefit from on-farm client-oriented research (De Villiers and Letty, 2001). The area comprised the resource-poor farming communities of Nkwezela, Hlafuna and Njobokazi, near Bulwer (Fig. 1), south-western KwaZulu-Natal Province, South Africa. The area has moderate to high agricultural potential, but soils are leached requiring expensive inputs of lime and fertilizers. Communal grazing of cattle, goats, sheep and horses is practised.

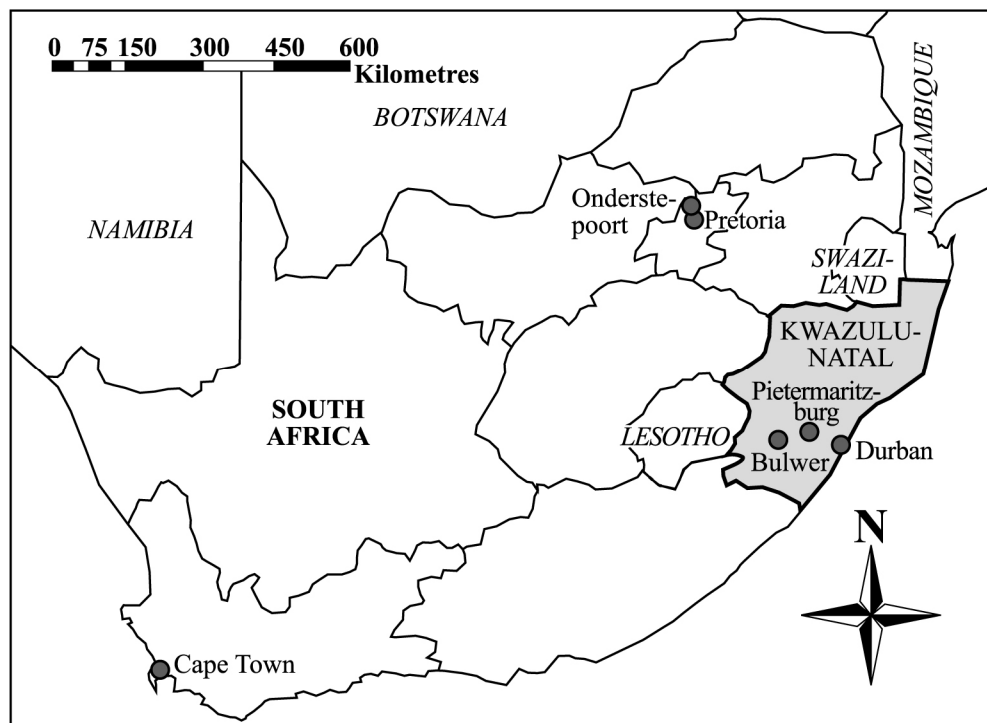


Fig. 1: Map of South Africa indicating the location of KwaZulu-Natal Province, certain major cities, Onderstepoort, site of the on-station work, and Bulwer, site of the on-farm work

The population of Nkwezela, Hlafuna and Njobokazi, essentially all of black African race, grew from 3 447 to 3 788 individuals between 1996 and 2001. Over the same period, unemployment rose from 26 % to 39 % (Ntsime *et al.*, 2003; Jennings, 2004). In 2001, the demographics of the villages were skewed with 56 % women, 44 % men and 58 % of the population under the age of 20. The proportions of households headed by traditionally vulnerable groups, namely women, children and the elderly, were 68 %, 3 % and 32 %, respectively. This situation was reflective of migration of the employable persons to work in the cities. Most individuals (> 90 %) had at least very basic primary education. Access to electricity, clean potable water, adequate sanitation and refuse removal were poor.

During initial studies carried out by the FSR Staff of the KwaZulu-Natal Department of Agriculture and Environmental Affairs in Nkwezela, chickens, goats and cattle were identified as being the most frequently kept livestock (De Villiers and Letty, 2001). A need for information on livestock diseases, the potential causes of livestock mortalities and the use of medication was expressed. General problems mentioned were theft, poor livestock production, animals in poor condition and insufficient grazing for livestock, mainly as a result of burning of the natural pasture. More specific problems affecting goats were diarrhoea, gastro-intestinal helminths, poor reproduction, diarrhoea, deaths due to unknown causes, coughing and theft (Mapeyi *et al.*, 2006). Research work in the nearby community of Impendle during 1998-2000 provided further evidence that helminths (specifically roundworms) and dry season feed shortages were a problem (Vatta *et al.*, 2002a,b).

An on-station experiment was carried out at Onderstepoort (Fig. 1) to provide some basic information (Vatta *et al.*, 2007b). To validate and assess the potential applicability of the results of this experiment under resource-poor agro-ecological and management conditions, an on-farm experiment (described in the present article) was then conducted in Bulwer. Supporting the farmers' need for information on goat health and management, such information was also packaged, tested and revised for relevance, clarity and usefulness.

PURPOSE AND OBJECTIVES

The primary aim of the work described here was to enhance the participation by resource-poor farmers in a goat health on-farm research project and in the development of appropriate extension materials. A secondary aim was to create an awareness of the potential to improve goat production in the wider goat farming community. Linked to these objectives, a further aim was to assess the effectiveness of the approach by examining the relevance and uptake of the goat health and management information in the community during the course of the study.

METHODS

Initial engagement

An initial information day attended predominantly by members of the Nkwezela community was held in December 2002 where the topic of roundworms was discussed. In February 2003 two focus group meetings were conducted by independent facilitators (Ntsime *et al.*, 2003). One focus group meeting was held with goat and non-goat farmers from Nkwezela and one with goat farmers from Hlafuna and Njobokazi. The focus group meetings were centred on goat farming and confirmed the important cultural role that goats play in the community, for example, for the payment of the bride price, or *lobola*, and during traditional ancestral rituals. Goats were also kept for sale and for food. Farmers indicated their willingness to receive training in goat health care. The facilitators recommended more structured training sessions than the *ad hoc* training that the FSR Staff was already providing. The attendees at the focus groups were reluctant to organize into a structure to assist them in selling or buying goats, because the farmers were concerned that they did not have equal numbers of goats and that this could lead to competition and unnecessary rivalry amongst the farmers. From August 2003 onwards on a monthly to bimonthly basis, information sessions were held which continued until May 2004 (see below). The on-farm research work started in January 2004 and continued until December 2005. A number of participatory activities with the community flowed from the initial engagement and are described in more detail below and in Fig. 2.

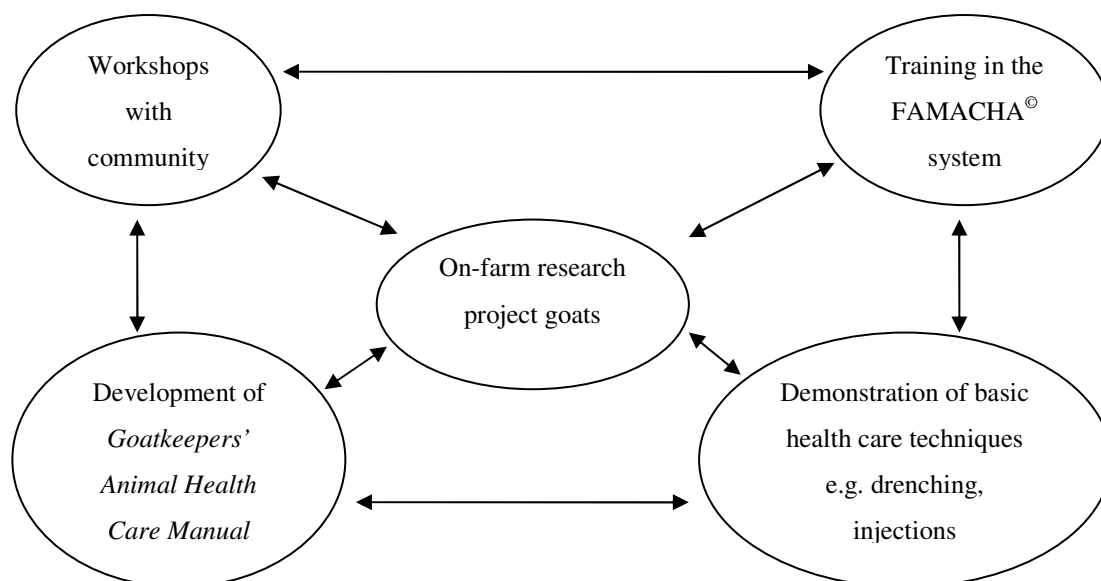


Fig. 2: Activities connected to an on-farm research project in Bulwer, South Africa, designed to increase the mutual learning of farmers and researchers

Participatory activities

Development of the Goatkeepers' animal health care manual. A manual was compiled to include information on disease and management problems of goats (Vatta *et al.*, 2006). The aim was to achieve a format and level of language which farmers could easily understand and use so that they could learn about, recognize and manage diseases in their goats. The manual was produced in English and then translated into the local language of IsiZulu, printed as spiral-wire-bound copies with laminated pages in A3 and A4 format and printed as laminated A0 posters. Using the posters in IsiZulu, the information was presented to a goatkeepers' interest group at ten information sessions during the period December 2002 to May 2004. This group had been formed from a group of farmers from Nkwezela, Hlafuna and Njobokazi who had agreed at a meeting in August 2002 to be interviewed by the FSR Staff about their goat farming practices (Mapeyi *et al.*, 2006).

The farmers of this interest group (including the farmers involved in the on-farm experiments) were personally invited to attend with their neighbours, however, the meetings were open to all livestock owners who wished to attend, i.e. the greater communities of Nkwezela,

Hlafuna and Njobokazi. Held in either the tribal or community hall of Nkwezela or Hlafuna, transport to and from the meetings was provided to assist attendance. The meetings were conducted in IsiZulu with translation into English where necessary. The meetings were opened with a prayer whereafter one or two topics were discussed. Attendees were encouraged to ask questions after each topic had been presented and to give comments on, for example, prevalence of the diseases and problems in their area. They were encouraged to ask questions about the health of their animals (not only goats). The meetings were closed with a prayer and refreshments were provided.

After each session, the researchers completed a self-assessment questionnaire to assess the relevance, usefulness and clarity of the topics discussed by the farmer group. Comments and questions of the farmers were recorded by the researchers and inputs from various experts in the field of goat health and production and in agricultural extension were sought. These comments were all addressed during the revision of the manual.

The *Goatkeepers' Animal Health Care Manual* was revised and a second English draft produced which was circulated for feedback at an 'International workshop on improving the well-being of resource-poor communities – The contribution of small livestock' (Smith *et al.*, 2006) held in Howick, KwaZulu-Natal, South Africa. Hereafter, the final English and IsiZulu versions of the manual were produced and widely distributed. A complementary booklet on *Worms in your goats, sheep and cattle* (Vatta, 2003) was also revised and translated into IsiZulu.

On-farm experiment. Towards the end of 2003, ten farmers of the goatkeepers' interest group that had at least seven weaned does were invited to make their goats available for the experiment. One of these decided not to participate. Four farmers' goat herds were included from Nkwezela, two from Hlafuna and three from Njobokazi. The homesteads of these nine participating farmers were visited every four weeks from January 2004 to December 2005 by the researchers. The experiment examined the effects of nutritional supplementation by means of urea-molasses blocks (Voermol Protein Blocks, Voermol, South Africa), and of anthelmintic (deworming) treatments on goat health and productivity. Four of the farmers' goat herds were supplemented with the blocks for comparison with the remaining five unsupplemented herds. Farmers were reminded

of the visit in person or by cellular telephone call by staff of the FSR Section during the week prior to the visit.

The farmers' role in the work was to assume the risk of undertaking the experiments, to provide time and labour to assist with the handling of the goats and, under the guidance of the researchers, to examine the goats for anaemia (according to the FAMACHA[®] system – see below) and drench anaemic individuals.

Demonstration of basic techniques. The visits to the farmers' homesteads provided the opportunity for examination of goats for anaemia, correct recognition of sick animals, correct drenching and administration of injections for the treatment of disease, and the correct feeding of urea-molasses blocks to be taught and re-demonstrated, on an 'as-needs' basis. Farmers were provided with urea-molasses blocks free of charge as well as free health-care treatments for their animals, where necessary.

Training in the FAMACHA[®] system. An important component of the training in basic goat health was the training in the FAMACHA[®] system. This is a system in which the colour of the conjunctival (eye) mucous membranes of individual sheep and goats are examined (Malan *et al.*, 2001). Those animals that are scored as being anaemic, as evidenced by a pale mucous membrane colour, are treated with an effective anthelmintic. In the present study, the anthelmintic, ivermectin (Ivomec Liquid, Merial South Africa), was administered orally at 400 µg/kg liveweight to anaemic animals. The system may only be used where the predominant cause of anaemia is wireworm (*Haemonchus contortus*) infection. The system is particularly suited to the study area as the wireworm is the predominant helminth infection in the goats during the warm, wet summer months.

Records of goats treated were kept by the researchers. Goats for slaughter or sale were identified by the farmer before the day's work began and such animals were not treated to avoid drug residues being present in the tissues at slaughter.

Workshops and meetings for ongoing assessment and reflection. In addition to the information days using the *Goatkeepers' animal health care manual*, workshops and meetings were held with the farmers to report back on the results of the research. The meetings were

advertised by inviting farmers well known to the research staff and encouraging these to invite their neighbours.

In June 2004, a workshop was held in the Nkwezela Community Hall. In addition to invitations, notices in IsiZulu were placed at shops and crossroads in the villages to advertise the meeting. Children at the local schools were given notices to take to their parents to remind them of the workshop. At the beginning of the meeting, participants were divided into a number of groups and a number of exploratory questions were asked by an extension officer who acted as a facilitator. The farmers were asked (a) whether they were aware of the goat research which was being conducted in the area, and if they were, what their perceptions of it were; (b) whether they normally kept medicine to treat goats when they were ill; and (c) whether the work that was being done would stimulate them to start keeping medicines or nutrient blocks for their animals. After the questions had been answered, the examination of dung samples for worm eggs and testing of blood samples for anaemia were demonstrated. In May 2005, a meeting was held mainly with participating farmers regarding the continuation of the research study through a second year.

During November 2005, questionnaire interviews to assess the potential impact of the project were carried out with the nine participating farmers by crop and horticulture members of the FSR Section, whose involvement with the goat project had been peripheral. In two cases, the farmer was not available on the day of the interview and the farmer's spouse, who had been closely involved in the project, was interviewed. The interviewees were asked whether they strongly agreed with, agreed with, were neutral towards, disagreed with or strongly disagreed with a number of statements regarding certain aspects of the project (Table 1). For comparative purposes, seven neighbours to the participant farmers were similarly interviewed (Table 1); four from Nkwezela, one from Hlafuna and two from Njobokazi. Each response was assigned a value from 1 to 5, with 5 indicating that the farmers strongly agreed with the statement and 1 that the farmer strongly disagreed. For example, if a farmer indicated that they would strongly recommend the FAMACHA[®] system, the response was assigned a value of 5, whereas if the farmer strongly disagreed, the response was assigned a score of 1. The median score and range for each question was then calculated. The results of the questionnaire were presented to the community at a meeting

in December 2005 and further comments recorded. The responses of the participating farmers were discussed, but those of the neighbours had not been analysed at that time and were not presented.

In March 2006, a workshop was held for technicians and scientists of the South Region of KwaZulu-Natal Department of Agriculture and Environmental Affairs. Two of the participating farmers, one man and one woman, who had increased substantially in self-confidence and knowledge, were invited to this workshop. They were given an opportunity to present their experiences of the project.

FINDINGS

The findings of the study are best considered in terms of the two main objectives, namely (1) to enhance the participation of the farmers in the on-farm research and develop the extension materials, and (2) to create an awareness of the potential to improve goat production in the communities.

Enhancing the participation of the farmers

On-farm experiment. Participation in the on-farm experimental work was good. The nine farmers were present on the day that they were visited for the work in 82% of cases (range for individual farmers: 44%-100%). On all occasions it was possible to visit and collect data at all the households during the scheduled four-weekly visits.

Three of the four farmers identified to feed the urea-molasses blocks were compliant with the requirements of the on-farm experiment. One of the farmers did not feed the blocks on a continuous basis during the first year of the study. She did not appreciate that she would be provided with more blocks when the ones she had, had been consumed and as a result she had been conserving them for use on rainy days only.

An analysis of the data collected indicated that the urea-molasses block supplementation had been equivocal in its efficacy (Vatta *et al.*, 2007a). While there was some effect on reducing the parasite burden in the first year of the study, this effect was not seen during the second year. Any effects of supplementation on the growth and reproductive performance of the goats were

generally not statistically significant. However, though not statistically significant, the symptomatic treatment of the goats with anthelmintic by means of the FAMACHA[®] system appeared to be linked to improvements in the reproductive capacity of the animals. This finding may have confounded any beneficial effect of the urea-molasses blocks (Vatta *et al.*, 2007a). The farmers' opinions, as assessed by means of the interviews in November 2005, mirrored these findings (Table 1). They had judged the urea-molasses blocks to be useful, but the response to the FAMACHA[®] system was much more positive.

When interviewed in November 2005 and at the meeting in December 2005, the responses of the participating farmers to the project in general and its results were positive (Table 1). The farmers said that their goats had showed an improved rate of kidding, a higher rate of twin kids born, an improved survival rate of goat kids, increases in the total number of goats and an improvement in the quality of the meat of slaughtered goats. At these exit interviews, most of the farmers indicated that worms were not a problem in their goats. This was interpreted to mean that worms were not a problem anymore, now that the farmers had learned how to identify potential problems and how to deal with them.

Demonstration of basic techniques. The information, training and advice provided during the project had been very useful (Table 1). The farmers or their assistants learnt to drench their animals and give subcutaneous or intramuscular injections where necessary. The male farmer at the workshop for agricultural technicians in March 2006 mentioned that he had learnt how to use the FAMACHA[®] card, how to look for worms in goats that are killed or die, how to trim the hooves of goats, how to lance abscesses, how to identify pneumonia in animals that died, and how to take samples from animals that die for submission to a laboratory for examination.

Training in the FAMACHA[®] system. Of the nine participating farmers, one or two persons were in the researchers' opinion satisfactorily trained in the FAMACHA[®] system at four of the households. Of the other farmers, four could not be trained because of age or poor eyesight and

Table 1: Responses of participating farmers and their neighbours to exit interview questions

	Participants			Neighbours					
	M ^a	(R)	n	M	(R)	n	M	(R)	n
<i>Productivity of goats</i>	Participants' goats			Neighbours' goats			Participants' goats		
Goats have improved	5	(4-5)	8	4	(3-5)	7	4	(3-5)	7
Goats producing more kids	5	(4-5)	9	3	(2-5)	7	4	(3-5)	7
Goats better condition	5	(4-5)	9	3	(2-4)	7	4	(4-5)	7
Goats healthier	5	(4-5)	9	4	(3-5)	7	4	(3-5)	7
<i>Livelihoods/income from goats</i>									
Goats more valuable	5	(4-5)	9	3	(3-5)	7			
Selling/bartering more goats	4	(1-5)	9	2	(1-4)	7			
Wealthier now	4	(1-5)	9	3	(1-4)	6			
More status now	4	(3-5)	9	3	(1-5)	7			
Goat farming more important	4	(3-5)	9	4	(3-5)	7			
<i>Information provided</i>									
Researchers gave useful advice	5	(4-5)	9						
Have learnt from training	5	(4-5)	9						
Have learnt from my neighbour				4	(3-5)	7			
Have heard about FAMACHA [®]				4	(1-5)	7			
Have been made aware of diseases	5	(4-5)	9	4	(2-5)	7			
Have been made aware of worms	4	(4-5)	9	4	(2-5)	7			
Have applied technologies				4	(3-5)	7			
Would like to learn more				4	(4-5)	7			
Diseases/worms not a problem	4	(2-5)	8	4	(2-5)	7			
Did not need training	2	(1-5)	9						
Researchers did not explain info	1	(1-4)	9						
Technologies not applicable				4	(1-4)	7			
Neighbour did not teach me				3	(1-4)	7			
<i>FAMACHA[®]</i>									
FAMACHA [®] is useful	5	(4-5)	9						
FAMACHA [®] improved goat health	5	(4-5)	9						
I will continue to use FAMACHA [®]	5	(4-5)	9						
I will recommend FAMACHA [®]	5	(4-5)	8						
FAMACHA [®] upset my farming	2	(1-5)	9						
Too many problems with FAMACHA [®]	2	(1-3)	9						
FAMACHA [®] did not work	1	(1-1)	9						
FAMACHA [®] difficult to use	2	(1-4)	9						
I will buy worm remedies	4.5	(4-5)	8	4	(3-4)	7			
Easy to buy worm remedies	4	(3-4)	9	4	(2-5)	7			
<i>Urea-molasses blocks (UMB)</i>									
Will feed UMB again in future	4	(4-5)	4						
UMB improved goat health	4	(4-5)	4						
Will recommend UMB to others	4	(2-4)	4						
Too many problems with UMB	2	(1-2)	4						
Difficult to purchase UMB	2.5	(2-4)	4						
Do not see need to feed UMB	2	(2-2)	4						

^a 1=strongly disagree; 2=disagree; 3=neutral; 4=agree; 5=strongly agree. M: median; R: range; n=number of respondents.

their sons or goat herds were not consistently available to learn the technique. The ninth farmer was not consistently present mainly because he carried out odd jobs in town.

Based on comments from farmers at the meeting in December 2005 and at the workshop for agricultural technicians in March 2006, the training in the FAMACHA[®] system had encouraged the farmers to examine their animals to see what was wrong with them. The female farmer that attended the workshop in March 2006 related that before the project started, she did not know how to care for the health of her goats. She said that she had known how to take her children to the doctor, but she had not known how to do this for goat kids. While the project had taught her how to treat her goats for worms according to the FAMACHA[®] system, the system had also allowed her to differentiate those animals that were sick as a result of worms from those that were sick from other causes. The male farmer that attended the workshop said that the system allowed him to identify early animals that were sick as a result of worms before serious signs of worm infection were noticed. Both these leading farmers were continuing to examine their goats for anaemia after the end of the project. While the male farmer had kept remedies before the start of the project, the female farmer was now buying anthelmintic to replenish her stock. Both farmers were apparently supplying medication to their neighbours for a fee. Community members now apparently consult them on how to treat their animals.

Creating an awareness in the community of the potential to improve goat production

Attendance at meetings and workshops. Excluding the meeting in May 2004, on average 14 farmers attended the information days for the testing of the *Goatkeepers' animal health care manual*. Twenty-seven farmers had been identified by the FSR Section for interviews on goat production in the area and these interviewees were invited to attend the information days. As such, there was attendance of about 50 % at the information days. Attendance did wane in March 2004 and extra effort was put in to encourage farmers to attend the next meeting which took place in May 2004. Forty-seven goat farmers and non-goat farmers then attended this meeting. The workshop for the greater farming community in June 2004 was attended by 57 members of the community, a record number and an indication of the positive awareness that had been created of the project. The meeting in December 2005 for reporting back on the results of the research was attended by 27 farmers.

Development of the Goatkeepers' animal health care manual. Based on inputs from the FSR Section who had interacted with the target farmers of Nkwezela, Hlafuna and Njobokazi as well as veterinary personnel working in the region, the first draft of the *Goatkeepers' animal health care manual* contained information on abortions, abscesses, coccidiosis, footrot, heartwater, mastitis, orf, pneumonia, pulpy kidney, rectal prolapse, roundworms and tetanus. There was a section on the basic procedures of injecting and drenching goats. The information was well received and numerous comments made. All kinds of questions were asked by the farmers which showed that they were hungry for information and that there is an insufficient flow of information from and to resource-poor people in this rural area. It was apparent that the farmers were familiar with symptoms of diseases and problems, such as abortions, orf lesions and diarrhoea. However, they were generally less familiar in associating these symptoms of disease with specific causes such as bacteria, viruses, protozoa and helminths. Based on the information gathered from the farmers and various other specialists to whom the manual had been sent for comments, the information on footrot and rectal prolapse was removed, while information on bluetongue, foot abscesses and liver fluke was added. More information was also provided on the general management of goats, on various other simple procedures (such as castration), on how to identify sick animals and on the correct use of medicines.

The demand for the manual was high amongst farmers, governmental and non-governmental organisations and other individuals. Almost 2000 copies of the English version were distributed nationally and internationally within a year of printing and several hundred in IsiZulu. As a result of the expertise gained through the development of the *Goatkeepers' animal health care manual*, the editor has been invited and contributed to two, separately convened, continuing education courses held by the University of Pretoria. The first course, in milk goat production, was organised for agricultural development agents from South Africa and Swaziland and the second, in animal health management, for veterinarians from the Southern African Development Community.

Workshop in June 2004. Fifty-three of 57 participants from the community at the workshop in June 2004 were goat keepers. Forty out of the 57 participants from the community were aware of the goat research being conducted in the area and they saw it as an important

initiative because problems were diagnosed and advice given to improve the livestock. Seventy percent of the respondents normally kept medicine to treat goats when they were ill. All of the participants indicated that the research project would stimulate them to start keeping medicines or nutrient blocks for their animals, but they required financial support.

Interviews with the neighbours to participating farmers. When interviewed in November 2005, the neighbours of the participating farmers felt that the goats of the participating farmers had improved (median score = 4), while their scores regarding the productivity of their own goats were slightly less favourable (median score = 3 or 4) (Table 1). While the farmers who had participated in the on-farm work indicated that their livelihoods had improved since the project started (median score = 4 or 5), their neighbours' corresponding scores were generally neutral (score = 3). The response to questions regarding the uptake of information by the neighbours gave somewhat conflicting responses. For example, the neighbours said that they had learnt from the participating farmers but also that they did not teach them anything new. The neighbours had been made aware of diseases and worms, wanted to learn more and wanted more information, but on the other hand they indicated that worms and diseases were not a problem. It seemed that while the neighbouring farmers were aware that potential improvements in goat health and management were possible, these farmers did not yet have the detailed knowledge of how to go about doing this. For example, the neighbours may have tried out the FAMACHA[®] system but not followed the examinations through on a regular basis, leading them to believe that the technology was not applicable to their situation.

Meeting in December 2005. Although much of the meeting focused on the on-farm research, the attendees were specifically asked what they saw as the way forward. The formation of a farmers' organization received some support as the suggestion was made that such an organization would be able to buy in bulk and thus save. Appreciation was shown for the training of farmers in the FAMACHA[®] system which was being extended to other farmers in the area by the FSR Section. Farmers who had not taken part in the on-farm research expressed a desire to learn from those who had participated in the work and these, in turn, indicated their willingness to assist others. Theft was mentioned as a continuing problem in the area.

DISCUSSION

The work had a leaning towards a ‘transfer of technology’ approach (Conroy, 2005). There was dissemination of information generated on-station and from the general scientific literature to an ‘audience’ of farmers (Lev and Acker, 1994). The researchers set the agenda and directed the process to a large extent in terms of designing the on-farm experiment and determining the frequency of visits and contact with farmers. They also acted as external advisors. In these aspects, the work was close to being a ‘centralized’, ‘top-down’ activity (Cristóvão *et al.*, 1997). However, the project moved away from a traditional transfer of technology exercise in which the farmers were simply passive recipients of technology and information. Rather, the researchers provided a learning agenda *for* the farmers but opened up the learning process so that it was not merely learning through the adoption of technology. The project facilitated the ‘acquisition of skills by farmers to engage with scientific enquiry’ while simultaneously allowing the researchers to share their knowledge and information (Worth, 2006).

The work achieved the first of its stated aims of enhancing the participation of resource-poor goat farmers in the on-farm research project and in the development of extension materials. The farmers’ participation was more than simply a process whereby the farmers were enlisted and their interest maintained for the duration of the experiment. Rather their participation was improved beyond this level and this participation led to adoption and ownership of what was learned – the farmers participating in the on-farm research stated that they had learnt a number of techniques, including how to use the FAMACHA[®] card for identification of anaemic goats; they were continuing to implement improvements in goat management beyond the duration of the project; they were sharing information with their neighbours and the community. This range of learning was found to extend beyond the intended degree of learning when the farmers indicated that they were themselves providing medication and advice to fellow farmers. These farmers were starting to act as important role models or ‘champions’ and as a very accessible source of advice and encouragement for other farmers in the area (Department for Children, Schools and Families, n.d.).

This enhanced participation was achieved through a number of aspects of the approach. A thorough preparatory phase (which included community meetings, interviews and focus group

meetings) had been carried out by the researchers during which the need for the work had been identified. Carrying out the experiment on-farm meant that any improvements in the goat herd were immediately visible to the participating farmers. Regular visits to the farmers' homesteads and a 'hands-on' approach meant that important concepts could be reinforced, techniques such as drenching and injections repeatedly demonstrated and the confidence of the farmers built up. The incorrect or partial application of extension messages was avoided. Regular meetings, including information days, meetings and workshops, with the farmers and members of the greater community played an important role. Participation was enhanced by paying attention to the particular 'socio-cultural environment' and 'circumstances in which project implementation' occurred in south-western KwaZulu-Natal (Cristóvão *et al.*, 1997), by conducting the meetings in the local language, by opening up the meetings to any community member and by taking questions on any aspect of animal health. In particular, matters of concern to those farmers of the greater community who were not direct participants in the on-farm research could be addressed. In this way, fears and misperceptions of the greater community towards the on-farm work were allayed.

The meetings allowed for an interaction and a flow of information between farmers and researchers, and opportunities for learning on both sides. Both the farmers and the researchers were able to investigate, assimilate and share information (Worth, 2006). The local farmers acted as partners in the work and the research scientists and the farmers were 'co-learners' (Lev and Acker, 1994). Farmers learnt from the information provided, while the researchers gained insight into the uptake of new knowledge and gaps in the knowledge of farmers. Perhaps, more importantly, the researchers gained insight into the farmers' systems and priorities. The researchers were able to immerse themselves, albeit transiently, in the life of the community, to understand better the problems, hardships and challenges faced by the farmers. The changes in the *Goatkeepers' animal health care manual*, especially the need for more information on the general management of goats, illustrated a shift away from the extension approach which looks narrowly at the technology of the researcher (and transferring that) to an approach that incorporates the whole system. It also supports the assertion that 'farmers are experimenters, innovators and active participants in change' and that extension needs to engage farmers in this vein (Worth, 2006).

The second aim of the project was to create an awareness of the potential to improve goat production in the greater goat farming community. Some awareness was created through the meetings and workshops with the community, but the findings of the study suggest that the process followed was less effective in disseminating the technology and information to the farmers not directly participating in the on-farm research. This is borne out by the contradictory responses of the participating farmers' neighbours to the questions of the exit interviews; their conclusions that the technologies were not applicable to them; the difference in perceived impact on livelihoods between the participating farmers and their neighbours – if uptake had been better than it was, the neighbours may have been expected to have had some improvement in livelihoods rather than these remaining the same. These responses, together with the mention of theft (which has nothing to do with goat illness) and the stated need for financial support to be able to 'adopt' the concept of greater goat care, all emphasize (a) the need to further engage the farmers of the greater community in a spirit of learning; (b) the need to understand that no matter how focused the researcher wants to be, farmers will always default to a wider system (for example, the whole goat system which includes even theft); (c) that the transfer of technology approach in which technology is developed in consultation with, but still largely *for* the farmer diminishes understanding and the ability to share with others – the farmers have learned the technology, but not the process by which the technology was developed. As such, they cannot in turn transfer it or engage neighbours in the exploratory process to arrive at the technology.

EDUCATIONAL IMPLICATIONS AND RECOMMENDATIONS

Changing the perception of agriculture in the rural communities is central to the realization of the enormous potential that agriculture holds for food security, gainful employment, income-generation and improved standards of living (De Villiers, 2006). The participatory approach, described in this paper, is suggested as such on-farm adaptive research and extension approaches help increase community confidence, awareness, and activity (Subair, 2002). Such was the result of the present study and by the end of the project, indications were that farmers were becoming more independent.

The FSR Section of the KwaZulu-Natal Department of Agriculture and Environmental Affairs has adopted this approach and is showing farmers, through demonstration and training, how best to exploit their livestock resources. This programme, if upscaled and improved, could be extended to include other communities in the province. Upscaling would involve such factors as: (a) facilitation of the formation of livestock associations to promote greater sharing of knowledge and expertise; (b) further training of farmers in 'new' communities in general goat care and management and the identification of local farmer 'champions'; (c) further specific training of 'champion' farmers so that they could provide local community animal health care and advice and supply small amounts of animal medication; and (d) the introduction of 'farmer field schools' (Minjauw *et al.*, 2003) to assist farmers to learn from their own shared experiences and to 'think for themselves' (Kumba, 2003).

In the present study, the farmers themselves suggested the formation of a livestock association by which the community could take the work forward. Such organizations could potentially assist farmers to better articulate their needs not only at the local level (Kumba, 2003) but also as they lobby government, the private sector, research institutes and other role players (Ngomane *et al.*, 2002) and should help promote a 'decentralised', 'bottom-up' approach (Cristóvão *et al.*, 1997). Therefore it would be of value if researchers and extension personnel assisted in the formation and strengthening of such organizations (Ngomane *et al.*, 2002).

The provision of basic information on general goat health and management to farmers in other goat-keeping communities of south-western KwaZulu-Natal province is a priority and, as stated above, some progress had already been made by the FSR Section (Mapeyi *et al.*, 2006). As was seen in the present study, repetitive meetings between researchers, extension personnel and farmers builds confidence in the farmers and the extension agents and leads to the emergence of farmer 'champions'. These farmers use their added skills as a focus and example for members of the community who would like to improve local farming and hence standards of living.

Some of the farmer champions should be given further specific training as community animal health workers in order to strengthen their knowledge levels, allowing them to provide basic animal health care in the community. This was effective in Namibia (Kumba, 2003) where farmer

champions provided essential veterinary services on a day-to-day basis and thus increased farmer involvement in delivery of state veterinary services. Such locally available assistance is invaluable in South Africa, especially given the scattered nature of rural homesteads and the vast distances that extension personnel must cover, often with limited transport resources (Ngomane and Flanagan, 2002).

The 'farmer field school' concept is another alternative that involves participatory activities, hands-on analysis and decision making (Rola *et al.*, 2002) and one which was adapted for smallholder dairy farmers in Kenya (Minjauw *et al.*, 2003). Groups of farmers meet at weekly intervals with an extension worker to share experiences. The main aim is to develop farmers' learning skills, rather than to increase knowledge on a particular technical issue (Minjauw *et al.*, 2003). The farmers' observation, record-keeping and decision-making skills are improved through 'agro-ecosystem analysis'. Farmers also engage in 'participatory technology development' with regard to livestock. This involves comparison of existing farmer practices, such as tick control and vaccination efficacy, of individuals both within and outside the farmer field school groups and 'ex-post analysis', in which farmers compare the new practices with those used previously. The introduction of such techniques to the communities of KwaZulu-Natal would help them to adapt appropriately new techniques to local conditions and help the farmers to explore and find appropriate local solutions.

In South Africa, agricultural teaching and training is mainly conducted by institutions of higher learning, research by the Agricultural Research Council (ARC) of South Africa and extension by the provincial departments of agriculture, but there is minimal cross-linking. There is therefore an ongoing and future role for integration between extension, research, tertiary institutions for higher education and farmers in this type of participatory community work (Ngomane *et al.*, 2002). The ARC, the statutory body tasked with 'the promotion of agriculture and agricultural-related activities' was criticized because, while it addressed problems of the commercial farming sector, less emphasis was placed on the small-scale farming sector and the linkage between the ARC, the provincial departmental research and extension units required enhancement (Ngomane *et al.*, 2002). This is a generally accepted viewpoint. Similar concerns

have been expressed about other service providers including government departments, non-government agencies and local development structures which serve the same community but tend to work independently (Ngomane and Flanagan, 2002).

The present study exemplifies how the successful integration of teaching, research, extension and farming may be formulated. The stakeholders included university scientists that provided a teaching and research function through the supervision and guidance of a graduate student, an ARC specialist discipline researcher, on-farm adaptive researchers and extension agents from the KwaZulu-Natal Department of Agriculture and Environmental Affairs and resource-poor farmers. Sessions on the compilation of animal health packages are now included in the University of Pretoria's continuing education courses. The senior author of this paper was invited to participate as a resource person in these sessions primarily as a result of the expertise he gained through the conduct of this project. This integration of teaching, research, extension and farming constitutes a successful and powerful tool which, if further supported and adopted, could be of great benefit to the resource-poor farming communities of South Africa and beyond. Ideally, students that are being trained as researchers and extension practitioners should be exposed to, and participate in, on-farm research projects as part of the main stream teaching curricula of institutions of higher education.

While the findings of this study cannot be generalized, they contribute to a growing understanding of the need for a serious review of South Africa's extension programmes. Few of South Africa's extension practitioners are adequately trained to be able to facilitate the range of learning that the approach suggested by this study demands. Most public sector extension practitioners have little or no formal training in learning theory. They are trained primarily as technologists (Worth, 2006). What extension training they do have is largely grounded in the 'technology transfer' mode (Worth, 2006) which has long outstripped its usefulness (Röling, 1995).

It is argued that the changes taking place in agriculture in the Republic of South Africa calls on extension practitioners to become more of a 'developer and facilitator of the specific learning process, content and outcomes which will drive his [/her] engagement with farmers as

“learners”.’ To make this possible will require extensive revision of Agricultural Extension curricula (Worth, 2007).

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GENERAL DISCUSSION AND FUTURE PERSPECTIVES

This study exemplifies how small-scale farmers with limited education can be genuinely and effectively engaged with highly technical science in a way that leads to the *in situ* identification and resolution of real and important problems. Further, this study demonstrates the possibility and practicality of engaging with farmers so that more than mere ‘technology transfer’ occurs. Farmers can be engaged as partners in learning, in which farmers, researchers, extension practitioners and scientists all contribute to and benefit from the process and outcomes. Farmers can also contribute by sharing that learning with other farmers and thereby become part of the overall extension programme.

With the participation of local farmers of south-western KwaZulu-Natal Province, the problems of gastrointestinal helminths, dry-season feed scarcity and poor reproductive performance were identified (see Chapters 1 and 5). Potential solutions were tested in a controlled manner through on-station, followed by on-farm experimentation. The potential solutions that were evaluated were urea-molasses block supplementation and the tactical and symptomatic anthelmintic treatment of goats. Anthelmintic resistance has emerged as a constraint to the management of helminth infections in domestic ruminants and this provided further justification to support the present investigations (see Chapter 2). The study addressed problems that are not only locally relevant but are common to goat farmers in the region, in other areas of South Africa, on the African continent and worldwide. Furthermore it acted as an example of how, throughout the process, study findings and other required information can be discussed with farmers, extension staff, scientists and other role players and all this information, including study recommendations, incorporated into locally appropriate educational extension materials, such as the *Goatkeepers’ animal health care manual* developed as part of this study. Such interactive activities can also indicate further areas suitable for both on-station and on-farm research, as well as extension. The

use of this approach, as it was applied in this instance, is now given more detailed consideration, as are ways in which the research and extension work may be taken further.

When potential solutions for the problems identified in the field were being researched, it became apparent that certain basic information was missing. This information included the optimal season in which to supplement the goats and exactly what effect the interaction of this intervention with tactical and symptomatic anthelmintic treatments would have *viz a viz* ameliorating the symptoms of gastrointestinal nematode infection and improving goat productivity. In order to examine these aspects, it was essential to eliminate all uncontrolled sources of variation as far as possible (Collinson, 1987).

Norman *et al.* (1994) and Stroud and Kirkby (2000) discussed the challenges of conducting livestock research compared with crop research and these difficulties include asynchronous stages of production in livestock, sex and age differences in animal herds, mobility of animals, and relatively fewer units in livestock than in crop trials. Livestock experiments tended to involve more risk to the farmer than crop research, because of the inherent value of the animals compared with that of the crops and because livestock experiments are often carried out for a longer period of time than crop experiments (Norman *et al.*, 1994). To eliminate the potential risks to the farmer and overcome the challenges inherent in on-farm livestock research, a role for on-station research was justified, where this was utilized to carry out basic research before the experimental work was moved to the farm. Variation in animal management between treatments could be limited as far as possible on-station so that biological responses to interventions could be compared (Snapp *et al.*, 2002). An on-station experiment thus appeared to be essential in the present study.

When the on-station experiment had been carried out (see Chapter 3), urea-molasses block supplementation was identified as an appropriate supplement for goats during the dry, winter period, although the intake of the block was low in this experiment (see Chapter 3, page 60). However, the effects of tactical and symptomatic treatments on gastrointestinal nematode infections were not fully assessed. This was because only light parasite infections were artificially established in the goats. [Faecal egg counts of 50-800 epg in a mixed nematode infection and worm counts of 1-1 000 *Trichostrongylus* spp. and 1-500 *Haemonchus* spp. are indicative of a light

degree of nematode infection (Hansen and Perry, 1994).] Ways in which the parasite burdens of the goats could potentially have been increased have been discussed in Chapter 3.

The recommendations of the on-station work were then tested on-farm (see Chapter 4). Here the approach tended to be researcher managed and implemented in a similar manner to that described by Norman *et al.* (1994). Given the variability in farmer management, and the stated need of farmers for information and training in order to improve goat management and health, this level of researcher management and implementation was felt necessary. This degree of researcher involvement allowed the use of urea-molasses block supplementation during the dry, winter season to be examined on-farm under controlled conditions. Despite this, the effects of the supplementation were inconclusive possibly because of the poor intake of the block, as had also been observed in the on-station experiment. Waruiru *et al.* (2004) examined the effects of supplementation with urea-molasses blocks of goats naturally infected with predominantly *Haemonchus contortus*. They found that the supplemented animals had lower faecal egg counts and lower worm counts following supplementation in the hot, dry season and better weight gains overalls than their non-supplemented counterparts. However, the average daily intake of the block per goat was 95 g in that study compared with the 42 g for the present study. The intake of blocks was expected to have been higher in the present on-farm study than on-station because of an expected lower availability of nutrients from the communal grazing than from the grazing and browse on-station. This was supported by the fact that the goats on-station had better body condition scores (2.8) at the end of the dry, winter period than the on-farm goats (1.8). Therefore, since the intake of blocks remained low, the problem may have been more to do with the fact that both the on-station and on-farm goats found the urea-molasses blocks unpalatable.

In contrast, the efficacy of the tactical anthelmintic treatment given before the expected peak in faecal egg count in the late wet, summer season was satisfactorily assessed on-farm because the overall nematode challenge was higher in the field than on-station, and this led to the recommendation being made that such tactical treatments be administered in late December or early January in south-western KwaZulu-Natal Province.

In FSR, wide replication of experiments across field sites is sought so that the level and consistency of responses to interventions can be assessed in the face of variations in farmers' circumstances and management practices (Collinson, 1987; Stroud and Kirkby, 2000; Snapp *et al.*, 2002). This study was restricted in its size and time-scale so that the variations inherent in the different grazing areas between and within villages, varying farmer management practices as well as herd and individual animal differences (*e.g.* age, stage of pregnancy or lactation, etc.) must be taken into account when analysing the results of the on-farm experiment.

Although researcher-managed, the on-farm work was feasible because the farmers' participation was more than simply a process whereby the farmers were enlisted and their interest maintained for the duration of the experiment (see Chapter 5). The on-farm activities provided the opportunity to develop a framework in which participatory learning could occur. Some of the participating farmers readily adopted the novel practices and moreover were starting to act as a locally accessible source of advice and encouragement for other farmers in the area, *i.e.* the farmers started to act as 'champion' farmers. This partially mitigates concerns about the use of a researcher-managed and technology transfer approach. The engagements with the farmers and, in particular, their sharing of knowledge with their peers, amply demonstrate the potential for strengthening the learning partnership between researcher and farmer. This is seen as a critical element in realizing the transformational agenda set for South African agriculture (Worth, 2006).

Areas were identified in which the participatory approach could be upscaled and improved and these included the strengthening of livestock farmer associations, identification of additional champion farmers and further training of farmers as community animal health care providers (see Chapter 5). The importance of integration of extension, research, tertiary institutions for higher education and farmers in this type of participatory community work was also emphasized.

A tangible product of the participatory process was the production of the *Goatkeepers' animal health care manual*. The manual found general acceptance and has now been widely distributed within South Africa. Requests for the manual were also received from other African countries such as Uganda and Zimbabwe. Initially 2 000 copies of the English version were printed, but demand for the manual has necessitated a reprint. The manual has been translated into

IsiZulu and IsiXhosa, local languages of South Africa, and translation into four other South African languages is underway, as is the production of an electronic version. A manual on pig health and welfare (Robinson and Penrith, n.d.) has been produced, based in part on the *Goatkeepers' animal health care manual* (M-L Penrith, TAD Scientific, pers. comm., 2007). Manuals on the health care of other important livestock species such as cattle and poultry could be expected to meet with a similar demand.

AREAS FOR FUTURE EXTENSION

A further dimension, not considered previously in this thesis, is the degree to which the extension personnel learnt through the project. A workshop was held for representative technicians and scientists of the KwaZulu-Natal Department of Agriculture and Environmental Affairs to report on the results of the project. This was held in March 2006 on completion of the field study. There was considerable interest generated in the results of the experimental work, the project recommendations, the dissemination materials and the approach followed. It was suggested that Agricultural Development Technicians should be given further training in the FAMACHA[®] system and other issues related to goat production. To achieve this, written training materials would be required as well as support for the Agricultural Development Technicians from the FSR Section with regard to practical demonstrations. These responses were similar to those made by the farmers at the June 2004 workshop (see Chapter 5). Thus while the extension service appeared willing, it lacked the practical knowledge to adopt and develop the results and recommendations conveyed at the workshop.

In contrast, the on-farm researchers and livestock technicians that formed part of the staff of the FSR Section had readily assimilated the concepts promoted for better goat health and management and had taken these messages out to other farmers and technicians (De Villiers *et al.*, 2007). Indeed, on their own initiative, the FSR Section embarked on a complementary programme, training more farmers and extension personnel in basic techniques to improve goat health and management. This occurred in various communities including Bulwer and environs and other areas in the province (De Villiers *et al.*, 2007). In some cases, farmers were encouraged and assisted to

train other farmers in their community using a Master Farmer Programme approach (Mapeyi *et al.*, 2006).

The difference in uptake between the FSR Section staff and the extension agents attending the workshop possibly resulted from the fact that the former had worked with the farmers while the latter were only made aware of the potential to improve goat farming, but did not have the practical experience. The FSR Section staff were physically involved with the training of the farmers on-farm, *e.g.* in the FAMACHA[®] system, and for presenting the information to the farmers during information days. This was done under the guidance of a resource person (*e.g.* a veterinarian trained in the FAMACHA[®] system). The on-farm research in itself had an integrated extension function, the on-farm researchers and research technicians fulfilling the role of extension agents in this arrangement (Stroud and Kirkby, 2000). An important aspect of this process was that the researcher or technician interacting with the farmers learnt that if he/she did not have all the answers, he/she could consult an expert and give the farmer an answer at a subsequent visit. This was a valuable lesson and undoubtedly contributed to improving the person's confidence.

The request for further training by the scientific and extension personnel of the KwaZulu-Natal Department of Agriculture and Environmental Affairs that attended the workshop in March 2006, and indeed for other extension agents in the Province, would therefore probably best be met through a participatory process in which the extension personnel and farmers are involved on-farm on a regular basis over a period of time, in a process similar to the one followed in the present study. Retraining of extension practitioners in the skills of facilitating learning, including their and the farmers' participation in investigation, assimilation and sharing, may also contribute to enhancing the farmers' understanding of abstract concepts and to building capacity and interest among the farmers in sharing with others.

In considering other ways in which the work may be further extended and other related forms of training that extension agents may benefit from, it is important to understand how the farmer wishes to develop and improve the farming operation, not the researcher and extension agent. The ultimate aim, after all, is to assist the farmer. It would be useful in this regard to understand how any proposed and agreed-on interventions (*e.g.* training in the FAMACHA[®]

system) are likely to affect the dynamics of the farming system, *e.g.* increasing the numbers of kids weaned may necessitate the need for better marketing channels in order to sell off the excess animals. As farming improves and moves away from subsistence farming and becomes more commercially oriented, the competencies of livestock extension agents and research scientists will also need to develop. Currently their input includes assisting farmers in preventing mortalities and improving production in their animals. In the future it could involve helping with aspects such as improving access to markets, ensuring the traceability of the product from production to distribution to consumption, value-adding to products, assisting with the managing of the finances of small businesses, the facilitation of the formation of farmer co-operatives and the establishment of contracts between producers and buyers for the supply of live goats, goat meat or goat milk products (Stroud and Kirkby, 2000; Roets and Kirsten, 2005). These are all areas, or potential innovation pathways (Stroud and Kirkby, 2000; Pound and Essegbey, 2007), in which extension agents and researchers could start to gain skills in anticipation of future requests from farmers as farming operations start to become commercialized. Very good recent examples of value-adding to products is that of wool sheep development by the National Wool Growers' Association, South Africa (De Beer, 2006) and the value-adding to goat meat by the Kalahari Kid Corporation, South Africa (Roets and Kirsten, 2005). Given the general paucity of non-technical/human science training given to South African extension practitioners, it has been suggested that substantial revision of Agricultural Extension curricula in South Africa may also be needed in order to train extension practitioners in these 'new' skills (Worth, 2007).

Certain non-governmental organizations in South Africa currently provide training that is geared towards the development of communities through livestock. The non-governmental organization, FARM-Africa, offers training for local government personnel, other non-governmental organizations, community-based organizations and communities (FARM-Africa, 2005). Topics covered may include land management, crop and livestock production, irrigation techniques, project and financial management and business skills. Scientific Roets, a company based in southern KwaZulu-Natal provides theoretical and practical training for non-

commercialized goat farmers in contract goat production and this also provides adult learners with a formal qualification (Roets and Kirsten, 2005).

An integral objective of the present work was to assist farmers to optimize goat production through better use of the resources available to them. The focus was on assisting those farmers who already owned goats, to improve their methods of goat farming. There are examples of development projects, however, where farmers who do not have livestock are assisted to obtain goats as new assets, because of the recognized potential of goat farming to alleviate poverty (Peacock, 2005). Such projects have been facilitated by Sokoine University of Agriculture in Tanzania (Muhikambebe *et al.*, 2002), FARM-Africa in Ethiopia, Kenya and South Africa (Peacock, 2005) and Heifer International in many countries worldwide, including South Africa (MacGregor, 2006). Utilizing a carefully planned, community-based and community-managed approach, an individual or family chosen by the group is provided with an animal on credit (Peacock, 2005; Ahuya *et al.*, 2005, 2006; MacGregor, 2006). This follows training of the individual in fodder production, improved management and basic animal health care. The individual is required to repay the credit in-kind by returning to the group one of the offspring of the donated animal and this young animal is then allocated to another individual. In Heifer International, this is known as 'passing on the gift'. Accountability to the farmer group promotes the sustainability of the credit scheme.

Should government extension personnel wish to implement similar programmes, they would benefit from interaction with these non-governmental organizations. In particular, this would serve to highlight the high level of dedication that is required of facilitators and the high degree of institutional readiness (*e.g.* in terms of approach, community interaction, appropriate skills and sufficient funding) that must be in place before embarking on such programmes.

The Kenyan experience in attempting to introduce milk goats for small-scale farmers provides an excellent example of the participatory development process that is required. In this country, initial attempts to improve local goat breeds for milk production were unsuccessful (Ahuya *et al.*, 2005). The approach was to multiply breeding stock on-station and distribute purebred and crossbred males through sale to farmers to improve their local goat herds. In the early

to mid 1990s, however, community-based and farmer-led goat improvement programmes were initiated in the Nyeri and Meru regions of Kenya. The aim was to produce a 75 % exotic breed, 25 % local breed crossbred goat and this was achieved through the establishment of breeder units and buck station within the community. The buck stations, maintained by the farmers, provided farmers with the opportunity to bring their goats for cross-breeding with the purebred stock. Inbreeding was controlled through organized buck rotations and the maintenance of records. The methodology proved so successful that improved dairy goat populations in the Central Province of Kenya grew at 16 % per year in the less than seven years since the initiation of the project compared with a growth rate of < 2 % achieved during the previous 40 years. The success in introducing, multiplying and sustaining the improved genetics was attributed to the use of a farmer-group-based approach. This included the establishment and strengthening of breeders' associations at the village level, which provided the opportunity for livestock marketing through exhibitions and auctions, accessing and management of credit, and the building of partnerships between farmers, extension agents and researchers. It also promoted the recognition of the role of community animal health care workers who provided 'within-reach' animal health care. A multi-institutional approach (including the non-governmental organisation, FARM-Africa, the German International Development (GTZ) organization, the Kenyan Ministry of Rural Development and farmers) helped to channel research efforts towards real rather than imaginary problems of the goat farmer, and the recommendations were immediately implemented.

AREAS FOR FUTURE RESEARCH

Alternative protein supplements for use in the dry, winter season

The problem of dry-season feed scarcity was clearly not fully resolved in the present study by the attempted use of urea-molasses blocks. In future studies, the screening of more options on farm may be useful, where feasible. Sutherland and Kang'ara (2000), utilizing a Farming Systems approach, identified contagious caprine pneumonia, worms, gall sickness and mange as important health problems in goats by means of surveys with farmers and veterinarians in the Lower Embu

and Tharaka-Nithi Districts of Kenya. They compared the efficacy against mange of various local concoctions, recommended commercial medications and a herbal preparation derived from outside the area. Two of the local preparations (castor oil plus tamarind and old engine oil plus *Albizia anthelmintica*) were shown to be effective, and the effects were immediately apparent to the participating farmers. When farmers from Gategi, another locality about 100km to the south, subsequently experienced a similar outbreak of mange, a tour was organized for these farmers to visit those that had participated in the study. The visiting farmers then returned home and applied the castor oil and tamarind mixture with good results. Through a formal on-farm experimental approach, the farmers' local knowledge was tested scientifically to provide a quick and effective technical solution to an important goat health problem, namely mange. Strong involvement of extension officers in the diagnosis, planning and experimentation encouraged ownership of the new technology and its swift uptake by farmers; strategic researchers provided support in identifying the parasite and had plans to identify the active ingredients in the local preparations. The on-farm screening of a 'basket of options' increased ownership, allowed farmers to formulate their own recommendations, and promoted interest in the dissemination of the results.

If one were to test a 'basket of options' to improve dry-season feed utilization by goats in the south-western region of KwaZulu-Natal Province, investigations into the poor intake and poor palatability of the urea-molasses blocks for goats, as seen in the present study, should be included in the 'basket'. Block hardness may be a critical factor in determining intake and blocks of softer consistency (Zhu *et al.*, 1991) or greater urea concentration (Knox, 2003) may be needed to ensure adequate intake for optimal nutritional benefit. Another factor in ensuring sufficient intake is to allow sufficient conditioning time when introducing the supplement for the first time. For example, it may take up to ten weeks before more than 80 % of sheep are consuming the target amount of the supplement and even after extended periods of supplementation, there may still be animals that do not feed on the supplement (Bowman and Sowell, 1997). It would be useful to see whether introducing the blocks in autumn (in April or May) would lead to an improved intake in the winter. Sheep inexperienced in eating supplements may learn more quickly to do so in the presence of experienced sheep or, in the case of lambs, experienced mothers (Bowman and Sowell, 1997).

Maternal influences may therefore also require investigation or exploitation to improve block consumption in goats. Although every effort was made to keep the blocks and their containers clean, some soiling did occur. Ways in which soiling of the blocks may be limited should therefore also be investigated, perhaps through the provision of smaller blocks which would be consumed more quickly. Hoste *et al.* (2005) have recently indicated that, in addition to protein, energy may also be a scarce resource for the goats during certain seasons, and that greater attention should be paid to the energy-protein balance of supplements in this species. The energy content of the supplementation was not examined in the present study and would be worth investigating in future studies.

While any formulation of the blocks would need to be discussed with the feed companies that produce them, the acceptability of these alternatives would best be investigated on-farm. Not only would this allow the suitability of the supplement to be examined under farm conditions, but providing the farmers with ‘multiple options’ rather than ‘single best bets’ would be consistent with a client-driven process rather than one that is researcher-driven (Stroud and Kirkby, 2000). As described by Sutherland and Kang’ara (2000) in their example of the control of mange in goats in Kenya, the provision of a ‘basket of options’ may increase ownership, the development of recommendations by farmers and the dissemination of the technology.

An alternative to urea-molasses block supplementation for parasitized ruminants, and a further potential option for the ‘basket’, is the use of bypass protein. This is found in the by-products of vegetable oil extraction, *i.e.* oil cake meals. For example, Magaya *et al.* (2000) showed a beneficial effect of cottonseed meal supplement with or without anthelmintic treatment on growth performance of parasitized weaner steers in Zimbabwe. Supplementation of ruminants with oil cake meal tends to be expensive and, as mentioned in Chapter 1, researchers have thus considered the use of locally available sources of protein such as leguminous browse species and their pods (Aganga and Wani 1998; Sikosana *et al.*, 2004). Sikosana *et al.* (2002, 2004, 2005) utilized complementary on-station and on-farm approaches to examine the potential of leguminous pods of *Acacia* and other browse species, a locally available resource in south-western Zimbabwe, as dry-season supplements for goats. On-station, they assessed the intake of the pods in castrated male

goats as well as the effects of feeding the pods on live weight gains and carcass characteristics (Sikosana *et al.*, 2002, 2005). The effects of supplementation on kid birth and weaning weights in does supplemented 45 days before and after kidding were also investigated (Sikosana *et al.*, 2002). Complementary on-farm studies were carried out with the assistance of communal farmers in Matabeleland South Province, Zimbabwe (Sikosana *et al.*, 2004). The fruits of *Dichrostachys cinerea* were shown to hold promise as a dry-season protein supplement.

The harvesting of the leaves and pods of such leguminous plants was not an option in the areas of south-western KwaZulu-Natal targeted by the present study, because there were very few such browse species here. However, this possibility should be investigated in other areas of the summer rainfall area of southern Africa where the plants occur. Moreover, the principle of identification of locally available sources of protein is one that should be considered in future studies of the type described in this thesis.

In Tanzania, using participatory rural appraisal techniques, workers identified and evaluated a wooden box technology that allowed crop residues and other dry forages to be baled manually (Massawe and Mruttu, 2005). Baled stover increased the payload and reduced the transportation costs compared with the traditional method of transportation of loose stover in a one-tonne pickup. Baling also reduced the space required for storage and facilitated feed budgeting. The technology has found widespread adoption in Tanzania, but also further afield in Bangladesh. Such technologies may also be useful for farmers in the Bulwer area. Here the farmers allow livestock to consume post-harvest crop residues (pers. obs., 2004), but conserving the forage may allow for a more rationed use throughout the dry, winter period.

Certain of the leguminous plants have high tannin levels which bind protein in the rumen at near neutral pH but release it in the abomasum at an acidic pH (Min and Hart, 2003). Interestingly, it seems that condensed tannins have been shown to have a direct anthelmintic effect on worms. It is speculated that the condensed tannins may bind to nutrients for larval growth or interfere with gastrointestinal parasite metabolism itself (Min and Hart, 2003). Wattle tannins have been shown to have a direct anthelmintic effect in sheep on a good plane of nutrition infected with intestinal nematodes (Athanasidou *et al.*, 2000a, 2000b, 2001). Max *et al.* (2006) showed that a wattle

tannin drench reduced the faecal egg counts of grazing sheep. While the condensed tannins may have beneficial effects, tannins at high levels may in fact depress rumen fermentation and have a so-called “antinutritional” effect leading to depressed feed intake, reduced digestibility and poor animal production (Min and Hart, 2003). There are also differences in the effects of tannins on gastrointestinal parasites in sheep and goats (Max *et al.*, 2004, 2006) with the effect on parasites being less marked in goats when compared with sheep. Goats are apparently able to degrade tannins in the rumen better than sheep (Min and Hart, 2003).

The warm-season perennial legume, sericea lespedeza (*Lespedeza cuneata*), has been shown to have an anthelmintic effect against *Haemonchus* spp. when goats are grazed on sericea lespedeza pastures (Min *et al.*, 2004) or fed sericea lespedeza hay (Shaik *et al.*, 2006). The plant has soil-binding and soil-enriching properties and is particularly suited for cultivation on poor quality soils. Sericea lespedeza has been cultivated with much success on a commercial farm in southern KwaZulu-Natal and the legume would appear to be suitable for cultivation in the communal grazing areas too. Here the farmers plant maize and other vegetable crops in small fenced-off areas and the sericea lespedeza, which cannot tolerate heavy grazing, could potentially be grown in such sites where it could be strategically grazed or otherwise utilized, *e.g.* to produce hay. It would seem to be an ideal species to consider especially in areas that have been degraded and eroded, which are commonplace in the communal grazing areas. Sericea lespedeza’s cultivation in these areas and its potential use to manage parasites should be comprehensively assessed on-farm, but there may be scope for on-station work to characterize and elucidate the mechanism of action of the tannins, to understand better the antiparasitic effects of the legume, particularly if field work gives inconsistent results (taking on-farm results back to the station) or for further investigations into the effects of feed processing on the anthelmintic activity of the legume (Terrill *et al.*, 2007).

Further investigations into the FAMACHA[®] system

As suggested by the on-farm work (see Chapter 4), further investigations into the potential beneficial effects of the symptomatic treatment of anaemic goats using the FAMACHA[®] system in improving reproductive efficiency on-farm are also indicated.

While the sensitivity of the FAMACHA[®] system in goats was evaluated to be 76-85 % in South Africa (Vatta *et al.*, 2001) and 94 % in the USA (Kaplan *et al.*, 2004), the specificity of the system was poor at 52-55 % and 36 %, respectively. These calculations considered animals to be anaemic when their haematocrits were < 19 % (South Africa) or ≤ 19 % (USA) and their FAMACHA[®] scores were 3, 4 or 5. This implies that several animals were identified as being anaemic that were in fact not anaemic (false positives). While not examined in sheep in the South Africa study, the corresponding values for sensitivity and specificity for sheep in the USA study were 92 % and 59 %, respectively. Thus while the sensitivity was similar in both species in the USA study, the specificity in sheep was almost double that in goats. Further work should therefore examine improving the chart's specificity for use in goats, perhaps through modification of the chart specifically for this species.

Interestingly, Burke *et al.* (2007) calculated sensitivities of the FAMACHA[®] system to be 59 % and 66 % in sheep and goats respectively using the same haematocrit cut-off value of ≤ 19 % and FAMACHA[®] score of 3, 4 or 5. Specificities were 69 % and 65 % for sheep and goats, respectively. The poorer fit of the FAMACHA[®] scores to haematocrit values in the Burke *et al.* (2007) study than in the Kaplan *et al.* (2004) study was considered to have resulted from the operators in the 2007 study being less experienced in assigning FAMACHA[®] scores than those in the 2004 study. This problem was exacerbated by the presence of few anaemic animals relative to non-anaemic ones so that the inexperienced operators' task of assigning correct eye scores became more challenging.

Investigations into the use of the FAMACHA[®] system in areas where *Fasciola* spp. (liver flukes) are a problem are advisable, since *Fasciola* spp., like *H. contortus*, also cause anaemia in their hosts. In the present on-farm study, the effects of *Fasciola* spp. were probably effectively eliminated through drenching all the goats with triclabendazole on two occasions. However, such

‘blanket’ treatments of all the animals are not conducive to preserving anthelmintic efficacy because of the risk of the development of anthelmintic resistance. As such, the development of recommendations for the use of the FAMACHA[®] systems in areas where *Fasciola* spp. occur as a contributing factor to the development of anaemia in small ruminants, should be investigated. Similarly, the testing of the FAMACHA[®] system would be equally useful in areas where anaemia-causing trypanosomes are a problem (in many areas of central, east and west Africa). Such work is currently underway in Kenya (Wellcome Trust Project 075812/A/04/Z) and includes on-station and on-farm components. The contribution of heavy tick burdens, lice (Bath and De Wet, 2000) and fleas (Smith and Sherman, 1994) in causing anaemia in goats, particularly in young or debilitated animals, is a further area for future investigation, particularly with regard to the potential application of the FAMACHA[®] system in areas where such ectoparasites are problematic.

Surveys for anthelmintic resistance in small-scale farming areas

Anthelmintic resistance has emerged as a serious problem on many commercial farms, and also in the small-scale farming sector in South Africa (see Chapter 2). Since the ultimate development of anthelmintic resistance is probably inevitable (Waller, 2006), it would be useful to be able to test and monitor for the emergence of such resistance on an ongoing basis. Currently in South Africa, survey work for anthelmintic resistance is hampered, among other things, by the lack of readily available assays. The faecal egg count reduction test, which is the most commonly used test, requires the use of a relatively large number of animals, something which is rarely available in small-scale farming systems. The test is also time-consuming and hence costly. The *in vitro* larval development assay has been adapted to the smallholder setting (Ancheta *et al.*, 2004), and the feasibility of the implementation of the test for routine screening of diagnostic samples as well as for research purposes should be evaluated in South Africa by, for example, Onderstepoort Veterinary Institute.

Availability of anthelmintics in villages

In South Africa, the poor access to anthelmintics and other stock remedies by small-scale farmers has been noted. Reasons for this include long distances that need to be traveled to reach outlets selling stock remedies, sizes of packaging that are too large for the number of animals requiring treatment, the farmers' inadequate knowledge of animal diseases and poor facilities to apply the products correctly (Gehring *et al.*, 2002). Gehring *et al.* (2002) found that emerging farmers within the Madikwe District of the North West Province of South Africa most commonly purchased products from farmers' co-operatives (retail outlets situated in larger towns) and pharmacies (also in larger towns). For the majority of farmers, this required a journey by public transport of, on average, 70 km. This was despite the existence of so-called Field Service Units managed by a parastatal organization with the study area. The reasons farmers preferred purchasing medication within the larger towns were that public transport was often still required to reach the Field Service Units but was more inconvenient to access and not more expensive than traveling to the larger centres. The products required by the farmers, especially vaccines, were not always available at the Field Service Units. This was partly because these Units did not have the facilities to store thermolabile products, such as vaccines. The administrative staff, who sold the medication, were themselves not always available. The staff also did not have any formal training on how to handle and store veterinary drugs properly or on livestock health. Products were sold at the Field Service Units at prices that were 10 % higher than in the larger towns.

These deficiencies in supply of stock remedies, which are not particular to the North West Province but common throughout small-scale farming areas of South Africa, should be addressed. Ways in which stock remedies, seed, fertilizers, and simple implements such as hoof trimmers can be made more readily available in these communities, at a reasonable cost, need to be explored.

A strategy that did reportedly work in improving the access of smallholder Kenyan farmers to veterinary drugs was developed as an integral part of the FARM-Africa dairy goat project described previously (see 'Areas for future extension', page 127, and Kaberia, 2004). The model consisted of Community Based Animal Health Workers that were supervised by Animal Health Assistants, who in turn were supervised by private veterinarians. The Community Based Animal

Health Workers supplied medication to the dairy goat group they were a member of, the Animal Health Assistants established rural drug shops which supplied medication to farmers and to the Community Based Animal Health Workers. The supervising veterinarian operated from a practice office within an 'agro-vet' shop, equipped with a telephone and located in a main town. The rural drug shops that exist in Kenya supply medication in small quantities that are affordable to smallholder farmers and meet their requirements in terms of small numbers of animals to be treated (pers. obs., 2005-2006).

At the same time that one wants to improve access to medication for small-scale farmers, one needs to ensure that there is proper quality control in the production of the medication and that the integrity of the products is ensured in distribution and storage for sale. Gehring *et al.* (2002), for example, found deficiencies in the storage of products for sale in the Field Service Units examined in their study. There are reports from Kenya and Uganda of the sale of substandard, adulterated or fake anthelmintics (Wanyangu *et al.*, 1996; Waruiru *et al.*, 1998; Magona and Musisi, 1999; Magona *et al.*, 2000). However, Van Wyk *et al.* (1997) have drawn attention to the apparent lack of quality control in the production of generic anthelmintics even by reputable companies. These authors tested the efficacy of three generic rafoxanide products available on the market against a susceptible *H. contortus* strain. While two of the products showed efficacies of 99.5 % and 94.7 %, the efficacy of the third product was only 66.2 %. Van Wyk *et al.* (1997) speculated that since all three products had been subjected to thorough efficacy testing including controlled slaughtering trials at initial registration, the ongoing quality assurance and quality control procedures of batches of the product were inadequate. They speculated that this may have resulted from international brokers obtaining batches of active ingredient from different sources than those used at initial registration of the products, a fact which is not required to be disclosed, but which would potentially affect the quality of both innovator and generic products. Consequently, the authors recommended that before registration of a generic product is approved, not only comparative bioavailability studies but also efficacy testing against dose critical parasites and stages should be required. Furthermore, each new batch of active ingredient purchased should be subjected to simplified efficacy testing (*e.g.* by means of a faecal egg count reduction test).

Alternatives to conventional anthelmintics

Investigations into options that may be used as alternatives to conventional anthelmintics would be useful, particularly those that would be practical for small-scale farmers to use. The potential use of one form of nutrient supplementation has been investigated as part of the present study, but various areas for further research on this topic have been suggested (see pages 131-135).

The farmers, who were invited to the focus groups which were conducted at the beginning of the present study, indicated that they used to use certain traditional medicines to treat their animals (Ntsime *et al.*, 2003). Ethnoveterinary plant preparations are used widely by poorer people in the developing world for the treatment of disease in animals (Githiori *et al.*, 2005) and various authors have documented and/or attempted to evaluate scientifically the efficacy of these preparations. Githiori *et al.* (2005) have described the shortcomings of the previous research, amongst others, the pitfalls of extrapolation of *in vitro* effects to *in vivo* efficacy. They conclude that definitive proof of anthelmintic activity for any ethnoveterinary product must be demonstrated through *in vivo* testing of such products against the target parasites in their definitive hosts, with due consideration for inclusion of sufficient animals for statistical analysis. Worm counts from the organs of treated and control animals should be carried out where possible. Furthermore, there is a need to involve traditional healers in the process of validation, to ensure that the medicine has been prepared in the manner of the healers. There is a need to safeguard the intellectual property rights of the traditional healers and the communities and for the results of any research to be relayed back to the farmers and healers.

Copper sulphate had been used as an anthelmintic from the turn of the 19th century (Wright and Bozicevich, 1931), but toxicity to the host was a problem and it was replaced by the use of phenothiazine in the 1940s (Reinecke, 1983) and later, in the 1960s, by the safer, broad-spectrum anthelmintics such as the benzimidazoles (Gordon, 1961; Hebden, 1961). However, the need to supplement ruminants grazing on copper-deficient pastures remained. Here, the need for frequent drenching of soluble copper salts and tissue damage resulting from the intramuscular injections of copper in various forms were problematic. Dewey (1977), wishing to find a safe method for the sustained administration of copper, examined the use of copper oxide needles as a potential source.

This work drew on the previous experience of Lassiter and Bell (1960) who had found that copper was less available to sheep from copper oxide needles than from copper oxide powder and from copper sulphate, chloride, nitrate and carbonate. Dewey (1977) determined that the copper oxide needles were retained in the abomasum of sheep and speculated that trace amounts of copper were solubilized in ionic form in this acid environment and absorbed from the gastrointestinal tract. This provided the ruminant with copper over an extended period (for at least four months at a dosage of 10 g of copper oxide wire particles). Judson *et al.* (1982) had observed significantly lower serum pepsinogen activities in grazing sheep four weeks after they had been treated with 5 g of copper oxide wire particles. They thought that this had resulted from an anthelmintic effect of high copper concentrations in the abomasal fluid. Whitlock (1940) had postulated earlier that an acid environment was required for copper compounds to be effective against parasites. Bang *et al.* (1990) therefore speculated that the ionic copper released by the copper oxide wire particles in the abomasum could potentially be exploited as an anthelmintic and examined the effect of administration of copper oxide wire particles to sheep on the establishment of *H. contortus*, *Ostertagia circumcincta* and *Trichostrongylus colubriformis*. They found an effect against the abomasal parasites but not against the intestinal *T. colubriformis*. Following that study, workers have examined the efficacy of copper oxide wire particles for their anthelmintic effects against abomasal nematodes in sheep (Waller *et al.*, 2004) and goats (Chartier *et al.*, 2000). Their efficacy against artificial *Haemonchus contortus* infection in Zulu goats in South Africa has recently been demonstrated (Vatta *et al.*, 2007). The use of the copper oxide wire particles as part of a nematode control strategy on-farm now needs to be examined, *e.g.* as a tactical treatment before the expected peak in faecal egg counts in the late summer season. The particles may also lend themselves to local manufacture and this aspect should be further explored.

A component in the long-term sustainability of farming has to be the breeding of host animals for worm resistance (Gray, 1997), and in this respect, the hardiness of the indigenous breeds should be preserved while their productivity is improved. McKenzie (1987) demonstrated an apparent innate resistance to *Haemonchus contortus* in indigenous sheep in Zimbabwe. The FAMACHA[®] system may be a useful and practical tool in the selection of resilient/resistant small

ruminants. Initial studies determined that haematocrits were a potentially useful indicator of resistance (as measured by faecal egg count) and resilience (as measured by growth and body condition parameters) to infection with *Haemonchus contortus* in Merino sheep in South Africa (Bath *et al.*, 2001). FAMACHA[®] scores, which were highly correlated with haematocrits, were also thought to provide a useful although less accurate measure of anaemia. Estimates of heritability of haematocrit and FAMACHA[®] scores were reasonably high. These authors suggested that, in the small-scale farming situation, those animals least able to cope with *Haemonchus contortus* infection could be identified by means of the FAMACHA[®] system and eventually culled from the flock. In a more recent study, Burke and Miller (in press) indicated that FAMACHA[®] scores could be successfully utilized to identify superior sires for parasite resilience/resistance in Katahdin sheep in the southern United States. There is scope to examine the potential resistance and resilience of the indigenous goat breeds in more depth (Hoste *et al.*, 2005).

CONCLUDING REMARKS

- In order to promote the development and sustainability of small-scale farming, innovation needs to be encouraged and farming needs to be presented as an interesting and attractive prospect. This is especially important if young people are to be attracted into the industry. To assist in achieving this, a more positive term than ‘resource-poor’ may be useful and that is why the term ‘small-scale’ farming has been adopted. The objective should be to focus on the available resources of the communal farming sector and ways to optimize the outputs from these systems (MacGregor, 2006).
- The importance of the commercial farming sector cannot be overemphasized, but for the long-term sustainable development of agriculture in the country, it is important to enable the small-scale farming sector to produce to its full potential. Moreover, there is much demand for sources of good quality, locally produced fresh produce and, with ever rising world oil prices and increases in local transport costs, there is no reason why the small-scale sector should not command a share of this potentially very profitable market. In this regard, the small-scale farming sector in South Africa is, as yet, a relatively untapped source of agricultural produce.

- This thesis presents the results of a study that used a participatory methodology to evaluate the efficacy of nutritional, chemotherapeutic and farmer-educational approaches to aid in the management of gastrointestinal nematodes in goats for the specific benefit of small-scale farmers. Further, it opens the door to understanding the benefits to be gained by applying this methodology with small-scale farmers in other production systems.
- The on-station study described in this thesis indicated that the supplementation of goats with urea-molasses blocks during the dry season was economically justifiable. The goats supplemented during this period had greater cold dressed-out carcass weights at slaughter than the goats not supplemented or supplemented in the wet season or in both the wet and dry seasons. Dry-season supplementation with urea-molasses blocks may be useful under certain extensive grazing conditions in the summer-rainfall area of South Africa, such as those found on-station at Onderstepoort. The results of this supplementation were, however, inconclusive when applied on-farm under the communal farming conditions of south-western KwaZulu-Natal Province. Further research into affordable and palatable forms of protein supplementation for goats is required.
- The efficacy of tactical and symptomatic anthelmintic treatments could not be properly evaluated on-station because of low nematode infection levels in the experimental goats. In contrast, the on-farm study indicated that tactical anthelmintic treatments would be beneficial and should be recommended when administered in December or January (in the mid-wet season), before the expected peak in faecal egg counts (in the late wet season).
- The symptomatic treatment approach which utilizes the FAMACHA[®] system appeared to be useful in terms of improving the reproductive performance of the goats and in terms of farmer acceptance and adoption, and is also recommended.
- Established information from the literature and new findings from the project were packaged in a *Goatkeepers' animal health care manual* and this book was an important product of the participatory approach employed in this study. There is a continuing demand for copies of the manual, in English and other South African languages.

- The use of the participatory approach in a communal farming context for experimental veterinary research and extension is relatively novel for South Africa. This study indicates that the methodology was both practical and acceptable and of considerable benefit to the development of goat farming in the target area. It proved to be an effective vehicle for the training of on-farm researchers and research technicians so that they were able to fulfil the role of extension agents. This study contributes to the understanding that one important key to realising the potential of goat farming rests in the learning partnership established among farmers, researchers and extension practitioners.
- The expertise gained in the development of the extension materials is being exploited in continuing education courses at the University of Pretoria, and the lessons learnt will undoubtedly continue to be of value for the ongoing professional development of extension agents, researchers and veterinarians. There is much scope for students that are being trained as researchers and extension practitioners to be exposed to, and participate in, on-farm research projects as part of the main stream teaching curricula of institutions of higher learning.
- Finally, the thesis suggests area for future research, including further investigations into ways of overcoming dry-season feed shortages and the monitoring of the efficacy and quality of anthelmintics, their cost-effective distribution and supply in small-scale farming areas, as well as alternatives to their use.

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Bless the Lord, whales, and everything that moves in the waters,

praise and glorify him for ever!

Bless the Lord, every kind of bird,

praise and glorify him for ever!

Bless the Lord, all animals wild and tame,

praise and glorify him for ever!

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